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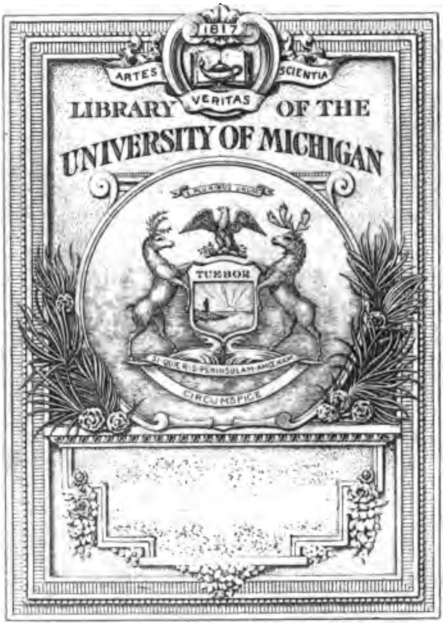

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THE

PHASIS OF MATTER;

BEING AN

OUTLINE OF THE DISCOVERIES AND APPLICATIONS

OF

MODERN CHEMISTRY.

BY T. LINDLEY KEMP, M.D.

> "Omnia mutantur; nihil interit. Errat et illinc
> Huc venit, hinc illinc." OVID.

IN TWO VOLUMES.

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THE CRUST OF THE EARTH,

OR THE

CHEMISTRY OF GEOLOGY.
~~~~

THE

PHASIS OF MATTER.

CHAPTER III.

THE HISTORY OF BRITISH GEOLOGICAL FORMATIONS.

A GEOLOGICAL formation is one or (as is almost always the case) a number of rocks that have been deposited by the same agencies and in the same sequence of time. Some of these formations have been deposited within the period of recorded history, and some are in the act of being deposited at the present moment. Perhaps a notice of some of these latter may elucidate the whole subject of formations.

There is, for example, the deposition at the mouth of the Nile called the Delta of the Nile. This is of great extent, the whole of it having been washed down by the waters of the Nile. As the river flows in the upper part of its course through syenite it will wash down a quantity of this mineral in a divided state, and also some of the plants and animals peculiar to the country, as lotus, papyrus, ibis, ichneumon, &c. All these are deposited upon the Delta; the minerals are agglutinated in layers, and the plants and minerals enclosed in these layers become fossils. Thus we have a geological formation produced.

This is not all. Every year the Nile overflows the province of Upper Egypt, and deposits much of its sediment and of the animal and vegetable substances it contains upon its surface. In this manner about three feet are added to it every thousand years; and if we suppose this process to go on for two hundred thousand years, there will be a formation lying over the surface of Upper Egypt eight hundred feet in thickness; that is, thicker than the majority of British formations.

It is by the action of water in this manner, or in some manner analogous to it, extending over a long period of years, that nearly all the stratified formations—*i. e.* formations in which the rocks lie in strata one over the other—are formed. If no disturbing causes act upon a formation or any portion of it, the strata lie horizontal to one another, as in *fig.* 78.; but if, as is often the case, by volcanic action, &c., they are heaved up and down, they assume various relations, after the manner seen in *fig.* 79.

Fig. 78.

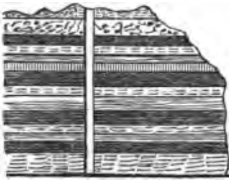
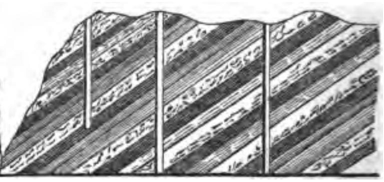


Fig. 79.



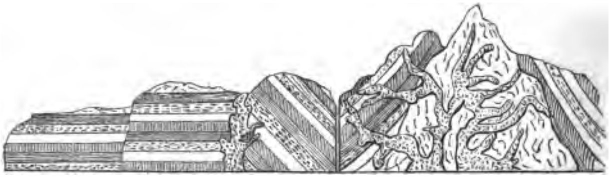
Of course it is not meant to say that it is always exactly in this manner by a river that the depositions are carried; marine currents, tides, springs, &c., have an analogous action.

Then we may take another modern formation. From time to time the volcano of Mount Vesuvius pours out immense quantities of lava; *i. e.* porous basalt associated with several other minerals. The quantity of this solid lava is indeed almost incredible. In one eruption alone, (that which occurred in 1796,) there were no less than 46,098,766 cubic feet of it ejected. In fact, so much has issued from it, that the whole surface round about is one thick mass of lava. It is clearly a recent geological deposit. When it comes out the lava is molten hot, and of course no life is possible in it, and it therefore contains no fossils. Moreover, not being deposited in regular strata, it forms an unstratified mass.

There is another peculiarity noticed in this formation. The holes out of which the molten lava issues are called craters, and these craters sometimes break out at one part of the district, and sometimes at another. The violence of the action that is going on during an eruption often causes cracks and fissures in the previously deposited lava around the crater. Into these cracks the fresh melting lava pours itself; and if the new lava be a little different in its composition and physical qualities, these veins or dykes, as they are called, will become very distinct.

A great many geological formations have clearly had their origin in this manner, and are the results of extinct volcanoes. They are unstratified and nonfossiliferous, and they contain dykes. We call them volcanic, igneous, or trap, rocks.

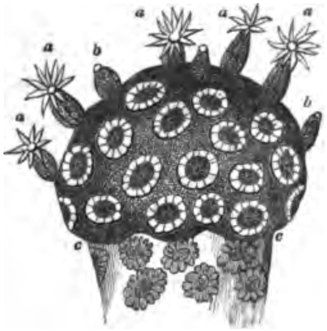
Fig. 80.



We will take another formation going on just now in the Southern Pacific. We refer to the coral reefs. Almost all the existing islands of the Pacific have been created by these zoophytes; and these are not only, owing to the same cause, enlarging, but new ones are being gradually brought to the surface. These little animals would appear to live on the microscopic sea plants, which yield them an abundant supply of carbonate of lime. From this they construct their skeletons. They live in community, having their skeletons stuck together; and when they die, which they do rapidly, these skeletons are pretty much a mass of chalk. These skeletons also enclose shells, starfishes, sea-urchins, and the like, which become cemented with them, and expedite the process of the formation. *Fig.* 81. represents a mass of a common coral; *a a* are the live animals with their polypes extended; *b b* are the same, the polypes being withdrawn into the cells; and *c c* are the skeletons of dead ones. At length the mass reaches the surface, and forms dry land, upon which a soil is eventually formed.

Now, more than one great formation of geology has had a similar or analogous origin. Such contain a large quantity of chalk, which is evidently the remains of the external skeletons or shells of myriads of myriads of extinct animals.

Fig. 81.



But the larger and most characteristic part of a geological formation may not be the remains of animal but of vegetable structures. There is, for example, a formation going on just now in the Gulf of Mexico, extended over an area of probably more than a hundred miles. Every day the immense Mississippi, 150 miles broad at its mouth, brings down vast quantities of mineral matter; but what is still more remarkable, also amazingly large rafts of drift wood, the pieces of which, according to Hall, are matted together, yards in thickness and leagues in extent. Layers of these are deposited in this large area of the Gulf of Mexico, alternating probably with strata of sandstone (mineral matter), and thus is quietly and silently preparing the great coal formation of the future.

The carboniferous or coal formation of the past, which we are now drawing from its long seclusion within the bowels of the earth, was doubtless formed in a manner exactly analogous. The surface of the globe during its formation was very warm, and favoured an extremely rank and luxuriant vegetation. The same heat would render evaporation great, and the eternal transit of moisture from spring to river, river to ocean, ocean to air, would be very rapid, and the streams therefore great and powerful. "Large rafts of drift wood," scarcely, we would think, however, so large as those of the Mississippi now-a-days, carried down these rivers, were deposited along with layers of sandstone, and thus formed that coal formation which has so long concealed mysteriously that fuel which is now serving us in such great store.

In fact, this subject of geological formations, often so puzzling to those unacquainted with mixed physical science, is merely a very intelligible illustration of that general law of the Phasis of Matter — All the matter that has existed in the world has been in it from the moment that the world by a volition of Omnipotence was called into being; but the great masses of it have been eternally changing their positions to one another. The history and progress of these changes we can to a certain extent trace. Sometimes we do this by observing the action of volcanoes upon mineral matter; more frequently by examining the fossil remains of animals and plants that each large mass of matter or formation contains, and which are quite different in each; and, lastly, by observing the order in which they lie over one another, that which is invariably the lowest being unquestionably the oldest, that which is invariably uppermost being certainly the most recently put there, and in the same ratio for all that are intermediate. The oldest formation that we know is the granite, and the youngest is the soil which we tread upon. But there may have been many formations older than the granite, the matter of which has either passed away into existing formations, or which lie deeper than man has ever penetrated to; and in like manner the soil under our feet will lie, when we are forgotten, and when our bones are its fossils, and probably constitute to those who succeed us a very ancient formation.

Having made these preliminary remarks, we now pass on to the history of British formations and their constituents. The map at the beginning of this Volume will perhaps facilitate our inquiries.

* * *

A. GRANITE FORMATIONS.

We are quite entitled to affirm that the materials composing the crust of this earth were, at one time, owing to their high temperature, in a fluid state, and also that the granite that we now possess is a portion of this once fluid mass, which has by cooling become solidified. These granite rocks have evidently been the result of igneous fusion; for they are unstratified and highly crystalline, and the crystals composing them have not been moved from the spot they were first formed in, for they present no traces of water-worn marks.

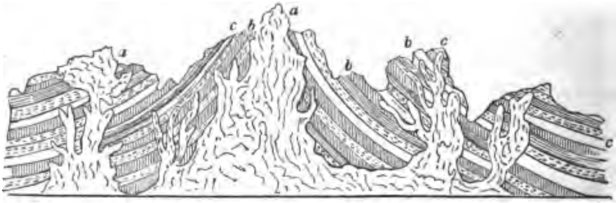
Notwithstanding this early origin of granite, the granite rocks still constitute a large proportion of the crust of the earth. Almost all the great mountain ranges, as the Alps, Pyrenees, Andes, &c., are mainly composed of them; and when we consider the origin and extent to which granite formations extend, we can easily understand that the chemical constitution of one mass of granite often differs widely from that of another, and that in fact the name granite refers more to a mass of crystalline rock evidently of a very old foundation, than to any definite combination of elements. The following may, however, be taken as generally correct with regard to the composition of granite.

The most essential minerals of granite proper are quartz, felspar, and mica; and hence the soil formed by its disintegration contains an abundance of potash, soda, magnesia, alumina, and some lime. Granite too, perhaps, invariably contains apatite, and sulphur minerals, together with iron and other metallic ores, and often gold and other native metals. But, beyond this general definition it is almost impossible to define granite as a chemical substance. Sometimes there is no mica, and the place of this mineral is taken by hornblende. This variety of granite, as just stated, is called syenite, and the soil that its disintegration produces contains a good proportion of lime, and is usually a very fertile one. Sometimes, in place of mica, there is talc; and this kind of granite is, as before mentioned, sometimes called protogine. Occasionally, instead of mica, or hornblende, or talc, we find chlorite; and then we have the serpentine of geologists. When the crystals of felspar are unusually distinct we have porphyritic granite, and when the surface takes the peculiar polish and appearance of written characters, the graphic granite. Not to particularise farther, we sometimes meet with granite without one of its usual essential minerals, as, for instance, quartz.

Usually granite formations form lofty mountains and elevated table lands; and it is to this that the general poverty of the soil that they form is to be ascribed. No sooner do the elements composing their surfaces enter into such combinations as are soluble in water, and therefore (see Book III.) capable of becoming converted into plants, than they are washed away to lower-lying localities. And it is owing to this, that, while granite mountains so often are covered by a barren soil, the little valleys that lie between them are frequently so fertile.

It is quite clear that the cooling, and consequent solidification, of the granite has been a very slow process. Indeed, it is very probable that at no great distance below our feet the chemical elements still exist in a molten state, such as the granite was in before it became hard. It is owing to this cause that we explain the occasional appearance of veins of granite through rocks that have undoubtedly been deposited long after the greater portion of the granite had become hardened, and which indeed have been formed by the disintegration of granite. In *fig.* 82. is shown the manner in which we find granite. *a a a* exhibits it in mountain masses, as it commonly occurs; *b b b* in veins that have broken through later and stratified formations, *c c c.*

Fig. 82.



The economic uses of granite, as well as those of the other formations, will be more particularly noticed, as far as they produce soil, under the chapter on Agriculture, in Book V. Gold, tin, iron, copper, zinc, and other mines are frequently worked among granite formations; the rock itself is very much used for building purposes, for which the hardness and durability of some varieties eminently qualify it; and some varieties of decayed felspar make the best kaolin for the use of the potter.

The granite formations are common in the British islands. In England they constitute considerable tracts in Cornwall (in which locality they are very rich in tin), in Anglesea, Cumberland, and other places; in Scotland they occur in Kircudbrightshire, and very extensively in Aberdeenshire and other parts of the Highlands, forming the most elevated land in the country; and in Ireland they constitute large districts in Wicklow, Waterford, Galway, and other parts.

B. METAMORPHIC OR GNEISS AND MICA-SLATE FORMATIONS.

These formations include several subsidiary ones, all of which have been formed from destroyed granite mountains; have been probably carried away by water, (and are hence in strata or layers); have afterwards been subjected to considerable heat, which has rendered them semi-crystalline; and have been deposited when the temperature around them was so hot that vegetable and animal life was impossible. For this last reason no organic remains or fossils are found amongst them.

Gneiss is sometimes so crystalline, and its strata so indistinct, that it is almost impossible to distinguish it from granite. Usually, however, its strata are quite distinct, its crystals much worn, and its texture very minute, showing the extreme disintegration that the particles of the previous granite that formed it have been subjected to.

As gneiss is formed by metamorphic granite, we find, as its main constituents, felspar, quartz, and mica. Gneiss is also a very metalliferous rock, containing ores of iron and lead in abundance. It likewise possesses many other minerals, and among them may be enumerated garnet, hornblende, and limestone. Frequently, too, dykes of greenstone and other igneous rocks, hereafter to be noticed, are found amongst it.

It occurs very abundantly in the north of Scotland and the north and north-west of Ireland. Its strata are generally much contorted; and hence the scenery has a peculiar, wild character, from the deep glens and lofty precipices thus formed.

Gneiss is very hard and decomposes very slowly, and from this cause; from its high altitude and from its precipitous nature, the soil formed upon it is usually poor and thin. Down in the glens, however, it is often fertile enough.

Mica-slate is merely a variety of gneiss formed from that kind of granite mentioned above that is deficient in felspar. Perhaps, however, mica-slate is sometimes formed by metamorphosed gneiss. Mica-slate is abundant in Scotland and Ireland, contains gold, silver, ores of iron, copper, lead, zinc, garnets, limestone, &c. It is not adapted either for building or slating.

Other varieties of these primary metamorphic rocks are chloride-slate, talc-slate, hornblende-slate, and masses of crystalline limestone. The names indicate their peculiarity. They run very much into one another, and it is often difficult to pronounce very decidedly to which of them a specimen exactly belongs.

* * *

c. CLAY-SLATE, GRAYWACKE, AND SILURIAN FORMATIONS.

These three formations, although probably deposited at very long intervals from one another, agree in having been the beds of seas and in containing a much larger proportion of alumina and less sand and lime than the formations previously noticed. Nevertheless, every portion of the rocks composing them is derived from the three previous formations. The cause of the predominance of the alumina is to be looked for in the decomposition of the felspar and its alumina being suspended in the water of the rivers. In fact, we see at present, after a flood, that the water washes along with a larger quantity of alumina than of the other constituents of the soil or rocks over which it passes.

The clay-slate formation consists of aluminous rocks many thousands of yards in thickness, consisting chiefly of thin slates remarkable for the readiness with which they cleave. Many of these do not contain more than a small quantity of lime, but consist mainly of silicates of alumina mixed up with decomposed schorl, &c., ores of lead, silver, copper, iron, bismuth, and other metals, and dykes of greenstone and other igneous rocks.

The graywacke is more varied in its composition. It consists of alumina, quartz, mica, jasper, and other minerals, and occasional beds of limestone. It was in these formations that life was first called into existence in the world. Doubtless marine vegetation was the first form of it, inasmuch as animals cannot assimilate mineral matter; but no traces of such have been found, and have probably been destroyed by the heat. A few fossils, zoophytes, mollusca, and crustacea (all marine animals) have been found, and it is to their remains that the limestone beds are owing.

These two formations are sometimes called the upper and lower Cambrian. The rocks constituting them cover nearly the whole of Cornwall, part of Devonshire, the west of Wales, a great portion of Westmoreland and Cumberland, and a large band, some thirty or forty miles wide, that crosses Scotland from the Mull of Galloway to St. Abbs' Head. It is this last that generally receives the name of graywacke.

In an agricultural point of view the soil formed by the decomposition of these rocks is bad, being, from its excess of alumina, very stiff and bad to work, and being usually very deficient in lime. If drained and limed, however, it makes a very fertile soil. But until these operations are performed it is fit for nothing but sheep-walks.

The scenery witnessed in these formations is almost always mountainous; but the mountains have invariably, or nearly so, a flat plateau on the top, which strongly contrasts with the peaked summits and lofty precipices beheld in granitic countries. These mountains are connected together in a very peculiar, elongated manner, with narrow, straight valleys between, down each of which flows a very clear stream of the purest water, the alumina through which it has filtered having taken from it every particle of organic matter. Trees grow with difficulty upon it, and scarcely ever naturally; but the grass is most verdant and luxuriant. The winds moving along the narrow valleys make a sound which the writer never heard in any other formation.

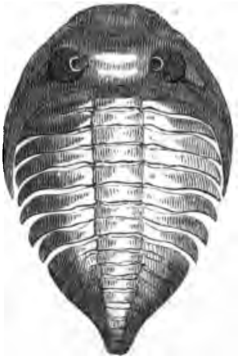
The Silurian formation is more recent than the two previous ones. Like them it formed the bed of a sea which was where the greater part of Wales now is. It is divided by Murchison, who is its historian, into two divisions, of upper and lower. The former of these extends over the eastern Welsh counties, and although not so decidedly aluminous as the rocks of the two previous formations, its chemical composition is characterised by a deficiency of lime. Hence its soil is naturally barren. The lower Silurian extends over portions of Shropshire, Caermarthen- and Montgomery-shires; and some portions of it, containing many animal remains, afford the soil the necessary lime, and these are fertile and rich-looking.

The sea, the bed of which has been at the bottom of these two formations, must have been limited, as no traces of it are to be found in either England or Ireland.

We might have decided that the Silurian system was deposited in the bed of a small sea about the size of Wales, and later than the deposits composing the Cambrian or graywacke systems, from its mineral appearance. The sedimentary character of the rocks is much more marked; the different minerals composing them have clearly been less acted upon by heat than has previously been the case, implying that the earth had progressed in its cooling; and the texture of them is much more loose. But we also now begin to find evidence of the existence of a good deal of life, and the Silurian system contains a great many fossils, both of animals and vegetables.

Thus, fossil sea-weeds, horsetails, and ferns have been found in it. Such were perhaps very abundant, although the heat and volcanic actions that seems to have prevailed towards the close of the formation have probably destroyed most of their structures. The numerous remains of animals that have survived testify, at any rate, to their numbers. Large coral reefs of the kind of corals called encrinites are found (forming limestone beds); shell-fish are frequent, and there are many remains of the trilobite, now generally believed to have been a crustacean animal. *Fig.* 83.

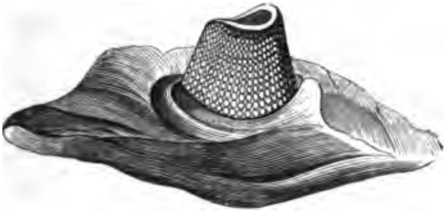
Fig. 83.



and *fig.* 84. represent the animal and its eye, the latter being magnified.

These eyes of the trilobites are remarkable in more senses than one. It must have been many years, probably many millions, not only since these animals lived, but since their race became extinct; and yet some of their dead bodies found in the condensed mud of this extinct Welsh sea, or in the present Silurian formations, contain the eyes in a state of remarkable preservation. But these eyes of the trilobites are most complex instances of creation. Each one of them contains at least four hundred lenses (the eye of man has but one); all, however, arranged so as to receive rays of light from above only, or at any rate from above and around, and therefore quite adapted for the use of any animal destined to inhabit the bottom of an ocean. Farther, these eyes of the trilobite point out to us, as has been remarked by Dr. Buckland, that both light and the atmosphere were in much the same condition in these early days when some slow river was washing away granite and gneiss into this Welsh sea to form the Silurian system, as they are now. "With regard to the atmosphere," he writes, "we infer that, had it differed materially from its actual condition, it might have so far affected the rays of light, that a corresponding difference from the eyes of existing crustaceans would have been found in the organs on which the impressions of such rays were then received. Regarding light itself also

Fig. 84.



we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye and of the eye to light were the same at the time when crustaceans endowed with the faculty of vision were placed at the bottom of the primeval seas as at the present moment."

We should observe, that these three transition formations, as they are often called, are abundantly permeated by igneous rocks. Indeed it is believed, that during their deposition the violence of volcanoes and the results produced by them were greater than at any other period, and that it was while they were forming that the principal mountain chains, as the Grampians, the Hartz mountains, the Andes, &c., were raised to their present height. These formations themselves, too, were, after they had been formed, raised by similar agency far above their previous level, and became, instead of sea beds, as they once had been, mountain ranges; and it was perhaps the heat that accompanied their elevations that destroyed some of their vegetables, which we should else find in a fossil state among their structures.

* * *

D. The Old Red Sandstone.

The old red sandstone is one of the most important of the formations. As its name indicates, it contains a large proportion of silicon, or silicates, amongst its rocks: and indeed it would appear to have been formed not from disintegration of rocks belonging to the clay-slate, graywacke, or Silurian systems; but from the remains of the gneiss and granite, the other portions of which, mainly the aluminous, had formed these clay-slate, &c. rocks, and the remains of which contained the greater portion of the original silicon.

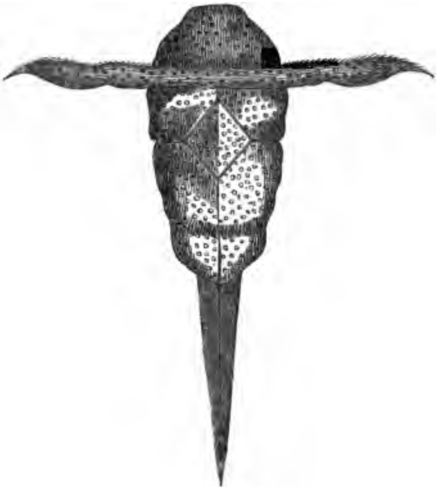
The formation is called that of the old red sandstone, because its rocks contain a large quantity of sand or silicon; because they are generally of a red hue from the admixture with them, of a quantity of iron; and it is farther named *old*, because there is a newer formation, characterised by consisting mainly of silicates tinged with iron, which has probably been formed by a disintegration of a portion of the old, and which receives the appellation of the new red sand stone.

The old red sandstone formation is sometimes of vast thickness, occasionally, in this island, being 12,000 feet. The rocks composing it, besides possessing minerals that contain silicon and iron, are generally rich in those into whose structure potash, soda, magnesia, lime, sulphur, phosphorus, &c., enter often largely. The vegetable fossils found in it are not very numerous; and its flora was probably nearly destroyed by the heat that attended the many volcanic actions that happened and that were natural to the globe during its deposition. Many of its animal fossils, however, have been found, and are very characteristic. One of the most abundant of these is that of a fish, one of the earliest of the created vertebrata, the ptericthys, figured in *fig.* 85.

In the British Islands the old red sandstone occurs at the surface in a portion of Southern Wales, in a corner of Westmoreland, a considerable portion of

Berwick and Roxburghshire; again in Haddington and a part of Lanark, and farther north in a tract of land that stretches from Stonehaven to the Island of Arran. It then appears in Caithness and the Orkney and Shetland Islands. In Ireland it forms a great portion of the superficies of Tyrone, Fermanagh, and Monaghan, and also a portion of Mayo and Waterford.

Fig. 85.



The scenery in old red sandstone districts is not, in general, very interesting, being often level, champaign, and non-undulating country. Sometimes, however, it rises into mountains, which are occasionally lofty, but which never present the bold and precipitous appearance of those seen in more primitive formations. Of these old red sandstone mountains, the Ochil Hills form one of our best examples. Few minerals are found in this formation by the lapidary, although he sometimes meets with chalcedonies, agates, jaspers, &c.; principally, however, in the igneous rocks that occasionally are met with in it. The sandstones themselves are often used for building purposes.

But, in an economic point of view, the old red sandstone formation is important, as furnishing the very best agricultural soil that we possess. Wherever it occurs in Britain, at least with one or two not very important exceptions, we have good farming and abundant crops. This is particularly to be observed in Scotland. A traveller in that part of the island may pass over a district that lies above this formation, and may witness every sign of good and productive farming; arable culture, large fields, clean kept thorn fences, large farmhouses and steadings, and crops worth, perhaps, on an average, eight pounds an acre; and he may go on, and ere he has got two miles from it, and over another formation, he will behold barren wastes, the sheep husbandry, or the raising of black cattle, no enclosures, shepherds' huts standing in wildernesses, and land dear at eighteen pence an acre.

The great value of land lying over and formed by the decomposition of old red sandstone, in an agricultural point of view, is, perhaps, to be attributed to three causes. Of these, one is the absence of abrupt hills, which, by their physical structure, confine the fertile soil to the valleys and glens; another, is the extreme admixture which the elements composing the crust of the globe have, ere it was deposited, by so many transformations undergone; and the third is, probably, the consequence of this latter, that by this intimate mechanical admixture various chemical combinations are promoted, some of which are soluble readily in water, and therefore (as will be afterwards seen) suitable for becoming the food of plants, and, consequently, for promoting a quick and luxuriant vegetation.

In order, however, that vegetation should be very rank and luxuriant, not only is plenty of food in a soluble state essential to the plants, but another condition is necessary; and that is a considerable amount of atmospherical heat. We may make a soil ever so rich on the top of a very high mountain and plant it, but if heat be absent nothing will grow at all; we may make a soil ever so rich lower down and plant it, and if heat be present but in small quantity we will have a crop but a stunted one; we may repeat the process lower down, and then we behold such crops as we perceive our farmers and planters raise: but if to a rich soil we add the temperature of a tropical country, the increase of vegetation is amazing. Land left to fallow in such a climate becomes in two or three years a mass of vegetable structures, — a perfect forest.

Now, we know, from reasons soon to be noticed, that at the epoch of the conclusion of the deposition of the old red sandstone formation, that part of the globe where Britain now is was very much hotter than it is at present; as hot, in fact, or hotter than the tropics are now-a-days. We would, then, expect to find in the next formation * remains of an abundant vegetation. Luckily for us this is the case; and the remains of the vegetation that grew on this fertile old sandstone, favoured by a temperature that we now do not possess, constitute coal, and give to the numerous series of deposits that then took place in many parts of the earth's surface (and which have since by subsequent deposits become covered) the name of the coal formation, next to be considered.

E. COAL FORMATION.

The coal formation consists mainly of layers of sandstone derived from the disintegration of portions of extinct parts of the previously mentioned formation, layers of shaly clays and limestones, partly derived from disintegrations of previous formations and partly from the skeletons of animals that dwelt in it; of ironstone, and of coal, which, as before mentioned, is composed of fossil vegetables, most of which have evidently during their existence had a terrestrial and not a marine residence.

Coal is formed by wood that is exposed to considerable pressure, and which has, by being excluded from the air, not been allowed to putrefy. Submitted to these influences, its chemical composition is little affected; but its physical structure is altered, being

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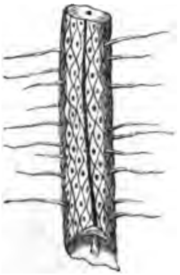
* Our limits compel us to omit a formation that in some countries was intermediate, that of the mountain limestone, so important as far as regards Ireland.

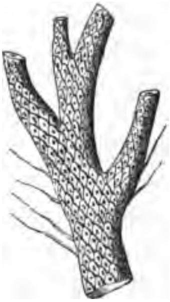
rendered much more dense and compact. Still the original vegetable structure may generally, by a little management, be witnessed; and it is ascertained that the flora that flourished so luxuriantly towards the close of the deposition of the old red sandstone formation, contained, at any rate, four hundred species. Most of these were gigantic equisetaceæ, ferns, mosses, cacti, pines, and plants allied to present bulrushes and bamboos. Four of the most frequently occurring plants that in their present state constitute our modern coal measures are indicated in the accompanying figures.

Fig. 86.



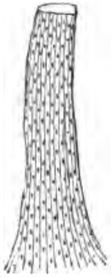
Stigmaria ficoides.

Fig. 87.



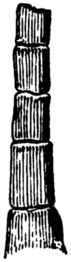
Lepidodendron sternbergii.

Fig. 88.



Sigillaria pachyderma.

Fig. 89.



Calamites cannaformis.

With the very important exception of the ironstone, the minerals contained in this formation are not, in an economic point of view, of importance.

The animals that appear to have flourished during the formation of the coal deposits were mainly fresh and marine shells, and fishes of a peculiar kind, allied to the saurian or lizard family.

The coal formations are abundant in Britain, and are probably the main source of her political strength. Most of her coal-fields are as well known as the names of her counties. The South Welsh coal-field occupies the whole of Glamorgan and part of Pembroke and Monmouth. Then the north of Somersetshire contains the Bristol coal measures. In Shropshire, Denbigh, and Flint we have the North Welsh coal district. Even still more important, we have the great coal formation of Yorkshire, Lancashire, and Northumberland; while in Scotland the Lothians, Fife, Ayrshire, and other parts of the west owe their prosperity mainly to these ancient forests, now ready for the use of man, occupying the surface a few feet above them.

In Ireland they are not so abundant. There is a small coal deposit in Monaghan, a larger one in Kilkenny and Queen's county, and one still more extensive in Clare, Kerry, and Limerick, and another in Cork. But the geological formation that corresponds with the coal in Britain is in Ireland that of the mountain limestone, and it is, perhaps, to this unlucky occurrence that the greater part of the evils of that unfortunate country are to be attributed.

Generally speaking, the soils formed by the decomposition of the sandstone, &c., of the coal formation are not naturally good, but are very capable of being rendered excellent by proper management; and, indeed, have very often been so rendered. The shales contain an excess of alumina, but the management of these heavy clay lands, at least those that lie over the coal, is now much better understood than it used to be. Some of the rocks lying over the formation in question, as for instance is generally the case in Durham, or at least in the west of that county, are deficient in lime; and either from this or from some other cause this district is generally considered the worst farmed in the empire. In the Lothians, owing to the superior culture and farming, it is not easy, from an examination of the crops, to pronounce whether the farm is over trap, coal, or old red sandstone.

Volcanic rocks of trap, greenstone, &c., are frequently found to have burst through coal formations.

The physical aspect of coal formations is not in general attractive. They have few hills, and in general, owing to the inhabitants looking upon agriculture as a secondary and inferior occupation, present a bleak and unfertile appearance. Sometimes, however, the igneous rocks both improve the bolder outlines of the landscape, and by their very fertile soil afford, even if badly cultivated, the appearance of fertility.

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F. NEW RED SANDSTONE SYSTEM.

The object of this Chapter is not to give an account of geological changes or geological formations; it is meant to be, in the first place, subservient to the elucidation of the leading plan of the work—the Phasis of Matter, and is intended to exemplify one of the great changes that are always, and always have been since the days of chaos, going on in this globe; to wit, the change of the mountain and land of one period into the ocean-bed of another, and of this ocean-bed being in its turn again the mountain and the habitable land of a subsequent day. The second intention of
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the Chapter is to give an account of the chemical constitution of the substances forming it, mainly with a view to trace the history of that other great Phasis of Matter,—the phasis of the rock with its dead inhabitants into soil, of that soil into vegetables, of these vegetables into animals, and of these animals back again to the soil, either to be converted into soil and then vegetables again, or perchance to be carried away with other disintegrated portions of the rock to form the fossils of a new formation only now taking place, which we at least, as corporeal philosophers, will never know anything about, and which may, perhaps, puzzle geologists some fifty or sixty thousand years hence.

But by the time that we get to the new red sandstones and subsequent formations the minerals composing the original granite have been so rubbed down and mixed together, that they no longer characterise formations. It is true that the animal remains of a subsequent formation give the distinguishing mark to its chemistry, but nevertheless the new red sandstone and the formations that come after it do not in this Book demand more than a passing notice.

After the formation of the coal forests and the upheaving of many of them by igneous action in some parts of the world, as in a district of the north of England, there was a small deposition of limestone particularly rich in magnesia; and perhaps at the same time, or a little later, there was deposited from the *débris* of the immense old red sandstone formation one that is called that of the new red sandstone.

This is found in the south of Devon; whence it runs north-east into Somersetshire; goes from Bristol up both sides of the Severn, and thence, stretching along the base of the Malverns, expands into a plain that takes in nearly all the counties of Warwick, Stafford, and Leicester. From this last place two divisions of it break off; one forms Cheshire, part of Flint, part of Lancashire, and again appears in Dumfriesshire; the other goes through part of Nottingham, Derby, and York-shires, and terminates at the river Tees in Durham. This formation also occurs to a small extent in Ireland.

Like the old red sandstone, from which it appears to have been very quickly formed, the soil that it gives origin to is very prolific.

* * *

G. OOLITE SYSTEMS.

After the deposition of the new red sandstone a great change or series of changes was effected in the general condition of the globe. There appears to have been a general uplifting of sea-beds, which became dry land, and a sinking of hitherto elevated tracts, which in their turn became covered with the waters. New formations began to be deposited, among which many kinds of new plants and animals lived. As many of the rocks of this have a texture which resembles in appearance the roe of fishes, this whole formation is called the oolite (*'ωόν, an egg*, an λίθος, *a stone*). This formation is only found in one or two isolated spots in Scotland and Ireland; but in England several varieties of it constitute important districts. The most districts of these are *a. The Lias.* This consists chiefly of beds of which the principal ingredient is blue alumina, but with which are mixed up varying quantities of silicates and limestones. They also contain bituminous matter, magnesian, and soda salts. It abounds, too, with animal remains. It forms a long strip of land which extends from the mouth of the Tees in Yorkshire to Lyme Regis in Dorsetshire. Owing to the preponderance of clay in it, its soil is heavy to work as arable land, particularly, as is generally the case, when it is not drained; but it is very favourable to the growth of grass, and much of it is in permanent pasture.

b. The lower Oolite. This is a varying mixture of clayey silicious and limestone, rocks. It commences at the south-western extremity of Dorsetshire, and runs north-east, forming the greater part of Gloucester, Oxford, Northampton, and Rutland-shires, and the north-east of Leicester. It then disappears from the surface, to appear again in the north riding of Yorkshire.

The soil that it forms varies very much according as the strata near the surface partake of an aluminous, calcareous, or silicious nature.

c. The middle Oolite. This is separated from the previous by a large deposit of clay, and consists of a variety of rocks; in which, however, the alumina sometimes very much preponderates. It runs along the edge of the upper oolite (next to be briefly noticed), and accompanies it from Dorsetshire through Wells, Oxford, Huntingdon, Lincolnshire, into Yorkshire.

The abundance of the alumina in many parts of this formation render it very impervious to water; and hence many parts of the soils formed by it are often under water, and constitute the fens of the midland counties.

d. The upper Oolite. This, like the former, is separated from the next formation by a great bed of rock, in which alumina very much preponderates, and which is called the Kimmeridge clay. It runs north-east from Dorset to Norfolk, and is rarely more than three or four miles in breadth. It again reappears in Lincolnshire and Yorkshire.

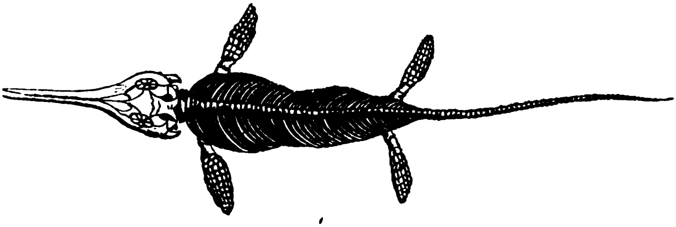
e. The Wealden. This is the last of the subvarieties of the oolitic formation that it is necessary to notice. It only appears at the surface in the centres of Sussex and Kent, where, however, it forms a pretty extensive district; the soil formed by the decomposition of which abounds in alumina, and which is therefore, until drained, not suitable for the growth of turnips and the arable culture.

The scenery witnessed upon these oolitic formations is, upon the whole, tame and monotonous. Over the lias indeed we witness wide valleys, with occasional mountain masses; but its general characteristic features are long slopes and gently undulating surfaces.

It is the organic remains that they possess that render this formation so attractive to the geologist, and which made Smith thank God that he was born upon the oolite. These remains indicate a great advance into the system that had been arranged for the gradual production of genera and species of living beings. Vegetation during its deposition was abundant, and in it may still be found the fossil remains of seaweeds, equisetaceæ, ferns, cycades, pines, lilies, &c. Many animals, too, flourished among it. Thus we find the remains of many zoophytes, star-fish, sea-urchins, crustacea, insects, and reptiles. Of these the most interesting perhaps are the ammonite (see *fig.* 90.), a species of shell fish that must have swarmed in the period in question, and the immense and extinct saurian, or lizard-shaped reptile, the ichthyosaurus (see *fig.* 91.).

Fig. 90.

Fig. 91.



Igneous rocks are occasionally to be seen in these oolitic formations; but these eruptions do not appear to have been common or violent.

The minerals of the oolite are of importance. The limestones of the lias are rich in lime, and are valued by builders for making cement or mortar for subaqueous buildings. The finer kinds of them are also used by the lithographer. Some of the clays, too, or more aluminous rocks, contain so much bitumen, that they will burn; and as these likewise contain pyrites (sulphuret of iron), the sulphur, during the combustion, unites with the oxygen of the air, forming sulphuric acid; and this, attaching itself to the alumina, affords to the burner the alum of commerce. The iron ore that the oolitic rocks contain is also sometimes worked; and that form of silicate of alumina called fuller's earth is obtained from other of these rocks. Some of the harder rocks are, too, much used for building purposes.

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H. The Chalk System or Formation.

Immediately over the Wealden is found the chalk formation. Like the rocks from the disintegration of which it is made up, the three most abundant of its constituents are silicates, alumina, and lime; but the sandstones are not often compact, but loosely adhering together: the clays are usually soft marl, and the limestones present that soft, earthy texture that characterises chalk. All this indicates the absence of any extreme pressure or exposure to much heat. Indeed, from this, and from its fossils and position, we infer that it is comparatively a recent marine deposit, and that its formation took place when the globe had considerably cooled.
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In England it may be traced, from Yorkshire, through the counties of Lincoln, Norfolk, Suffolk, Hertford, Bedford, Buckingham, Wilts, Dorset, to the Isle of Wight. In none of these localities is it permeated with igneous rocks. In Scotland it does not occur at all; and the small tract of it in the north-east of Ireland is distinguished by being associated with igneous rocks.

The more important minerals obtained from this formation are chalk, fuller's earth, and flints.

The character of the scenery of this formation is peculiar, and consists of those easy undulations called wolds and downs. It is not naturally productive of trees, but its herbage is excellent; and to this and to its extreme dryness are, perhaps, to be attributed its being generally a pastoral country. It forms, however, good arable land; but, for some cause or other, it has not been so well managed as districts naturally less fertile.

Besides many other fossils, the chalk contains one mammal one.

I. TERTIARY FORMATIONS.

The tertiary formations include all those that have been deposited since the cretaceous. They were formerly considered to be superficial accumulations, not distinguished by containing peculiar fossils, and not referable to any distinct period or order of succession. Since Cuvier's researches into the tertiary clay formation, on which Paris is situated, the tertiary formation is acknowledged to be a distinct one, consisting of regular strata, which contain the remains of extinct animals.

As we would have expected, all the tertiary formations are limited in extent. The gradual elevation of strata that had formed ocean-beds naturally reduces the limits of newer formations. Thus, the chalk that we have above alluded to forms comparatively small depositions, and the different tertiary ones are extremely localised; hence we can only notice the tertiary depositions of the London and Paris clay and one or two still more recent ones.

In these tertiary formations of England (no tertiary formations are found in Scotland, Ireland, or Wales) no igneous rocks are found, although they have often been thrown into ridges and hollows, evidently from subterranean action. Their organic remains are, however, important; and we find in their rocks, besides the fossils of such plants and animals as have before come under our notice, plenty of dicotyledonous trees, birds, and gigantic quadrupeds. And, what is more, a great many of all these belong either to remaining species or to allied members of remaining species.

Thus, the number of fishes that lived during the deposition of these tertiary formations was very great; and among the reptiles, not only do we find that the oolitic saurians have passed away, but we behold the remains of undoubted crocodiles, snakes, and frogs, and also still existing genera of turtles. In the Paris clay birds have been discovered that belong to the present genera of buzzard, owl, quail, woodcock, sea-lark, curlew, and pelican.

The fossil mammalia of the tertiary formations are, however, the organic remains that have received the most attention. More than fifty species of these are now known which are now represented by only four living species; namely, the daman of the Cape, and three tapirs. But there are two or three species of monkeys; rather more marsupial animals; a kind of a mole; many carnivorous animals of the nature of bears, hyenas, cats, weasels, &c.; several gnawing animals, as those of the beaver, rat, and hare tribe; some cud-chewing ones, as stags and antelopes; and one or two species of whales. But even still more interesting are the fossils of gigantic examples of the toothless animals of the nature of the sloth, and of the thick-skinned ones, as horses, elephants, and the altogether extinct mastodons, dinotheriums.

The vegetable remains of the London and Parisian clay are very numerous. In them remains of coniferous trees, willows, elms, palm-trees, and many others, are common. Some of these have been converted into a variety of coal called lignite, and which is excavated for fuel. Both the animal and vegetable fossils found in the French and English tertiary formations indicate a temperature higher than the one now existing over these localities.

K. POST TERTIARY OR SUPERFICIAL ACCUMULATIONS.

All the accumulations that have been formed by the disintegration of either tertiary or more ancient rocks belong to this division; and their name is legion. Some have been deposited by seas; some by lakes, rivers, and springs; some by volcanoes, &c. Here we can merely notice, and only notice, for its perfect composition must be deferred until the next Book of this Volume, that superficial accumulation formed over all the formations — soil. The mineral composition of soil is entirely derived from the disintegration of the particular rock over which it lies. Sometimes, as is occasionally the case over very silicious strata (as in the Great Desert), there is so little alumina and lime, that the soil has no power of sticking together, and is barren. But in general, as we have seen, that almost every rock, and invariably that congeries of rocks that occur in a formation, contains silicon, alumina, lime, magnesia, soda, potassa, chlorine, iron, sulphur, phosphorus, and water, (*i. e.*, oxygen and hydrogen); so also does every soil, save exceptional ones, such as the sands of the desert, contain silicon, alumina, lime, magnesia, soda, potassa, chlorine, iron, sulphur, phosphorus, and water; and a great proportion of these elementary bodies are united together in combinations that are more or less soluble in water.

* * *

L. THE IGNEOUS ROCKS.

Before concluding this Chapter, it is necessary to notice the volcanic rocks that we find occurring in almost every formation. They are principally composed of obsidian, pumice, greenstone, jasper, amygdaloid, &c. And from these rocks containing a large admixture of the bodies before enumerated the soil that they form is almost always very fertile.

Thus, when we consider the chemical compounds forming the structure of the globe; either those, as the rocks that have always been dead matter, or the organic remains that, having once been vitalised, have returned to the kingdom of death, we perceive a constant Phasis, or change. The original granite, of which this crust once entirely consisted, is passed into other formations: of these formations, the larger extent has been again transmuted; and the whole of the remaining granite and the remaining formations is, by slow but sure degrees, every second becoming disintegrated, and their substances passing into conglomerations destined to be future formations. This is one, and an interesting instance, of the great leading idea of nature, of constant material change and interchange. It, however, only refers to mere inanimate matter, and to such a Phasis as occurred, not only before man was created, but before the most insignificant moss or sea-weed was called into being, and which would continue, were vitality to depart from this earth. We pass on to the consideration of the extension and development of this Phasis of Matter, and to inquire into the structure of living and of intelligent beings, and whence they acquired that physical structure, and what, when they die, becomes of it.

BOOK III.

MATTER VITALISED,

OR

THE PRESENT STATE OF ORGANIC CHEMISTRY.

CHAPTER I.

GENERAL INTRODUCTION.

The student who has acquired a correct conception that the matter of the organised world, of animal and vegetable structures is identical with, and indeed derived from, the inorganic,—the air and the soil,—has made a great step in the philosophy of matter. It is of the last consequence, however, that the ideas entertained upon this subject should be very exact.

In the first place, it is necessary to bear in mind that when the elements of the soil enter into a living organism, they entirely pass out of the realm and control of ordinary inorganic chemistry. Chemical affinity perishes and dies as completely as life does after an animal has heaved its last sigh. The elements that exist in bodies, although the very same elements that we have hitherto considered, do not so group themselves and form such compounds as we have seen them do in the laboratory and in the rock. In their composition, in their properties, in their very physical conformation (for, notwithstanding what has been recently said, they never crystallise), the compounds formed by the different grouping of the elements in living structures are altogether peculiar to and different from inorganic compounds.

Another very great peculiarity characterises them. We have seen that, when in the laboratory, we can, as if we had a magician's wand, decompose and recompose almost at will. We can take sulphur and oxygen, for instance, and make them unite so as to form fiery and corroding oil of vitriol; we can take the substantial metallic iron and make it unite with oxygen and crumble into a powder; and we can make the vitriol and the iron oxide join together and form a transparent crystallised neutral salt.

So we can decompose organic structure; but we cannot, and never will be able to compose one. To do so would be to create vitality; a thing as much beyond the capabilities of man as the creation of matter. The possibility of doing some such impossibility has, however, been maintained. Paracelsus believed, or affected to believe, that it might be managed; and in our own time the increase of our knowledge regarding organic chemistry has led some to hope that this may be brought to pass. It may, however, be safely laid down that the artificial construction, by means of chemistry, of a really living organic principle is an utter impossibility.

Another very important distinction requires to be kept in view. Organic chemistry and the chemistry of life are not the same things. In the body of an animal that was alive a little ago, and which is not fully dead, we find certain substances, as fibrine and gelatine, having a distinct chemical composition, and very distinct properties, and which are in all respects different from any compounds that the same elements would form in the crust of the earth, or in the laboratory of the chemist. Hence we are entitled to say, that in structures that were recently portions of a living being, these compounds are to be found, and the business of organic chemistry consists in investigating the composition and property of these and of analogous compounds. But while we may perhaps think ourselves entitled to infer that some or all of these compounds exist in the body while it is fully alive and performing its functions with energy, we certainly cannot say or decide that they are so with certainty. While, then, the object of organic chemistry is to investigate the composition and properties of the various compounds that are found in animal and vegetable structures in that interval that elapses between their being fully alive and fully dead, the object of the science of the chemistry of life is, by inferences from these discoveries of organic chemistry, and from recorded observations of physiology, to try to determine what are the changes that matter undergoes in its continued Phasis at the time it is contained in the structure of plants and animals, and is entirely under the control of the laws of vitality.

Accordingly in this Book an account of the more important facts that have been ascertained with regard to organic chemistry is attempted; and in the following book (Book IV.), on the Chemistry of Life, an essay will be made to trace the matter that is taken in by the mouth or roots, the leaves or lungs, through its progress in animals and plants, until by inanition or death it is restored to the dead world and the laws of chemistry.

We have already seen something analogous to this.

Although the chemistry of the crust of the earth is not intelligible without a knowledge of the chemistry that is learned in the laboratory; and although the elements under consideration are identical, yet the compounds formed by nature are not exactly those we usually synthetically construct by art, and many of those quite familiar to us in the midst of our apparatus and balances are rare or unknown in nature.

There is another point to which the student of organic chemistry requires to give his attention. From the time that the more striking phenomena of life in an organised structure depart, to the period at which its elements fairly return to the control of ordinary chemistry, there is usually a considerable and often a prolonged interval. We can easily fancy that this change that takes place from an organic principle, such as exists in a very newly-killed animal or plant, to mere dead matter, such as is found in the soil or the bottles of the chemist, is not immediate and direct, but that it passes through one or more intermediate stages; and such is now well ascertained to be the case. Principles like gluten and fibrine, for instance, contain a very considerable quantity of nitrogen; and this nitrogen was originally all derived from the soil in the shape of some nitrate, or some ammonia, which was absorbed by the root of a plant, was appropriated to form gluten, and this gluten was converted into fibrine by passing into the stomach of an animal. But when life departs from the fibrine it does not at once return to the soil as a nitrate or other nitrogenous dead compound. In the animal body, portions of which die daily, the dead fibrine becomes converted into a substance called urea; a compound that approaches more to the nature of an inorganic principle, but which is still quite distinct from such: and if gluten or fibrine be allowed to rot, they are converted into ammonia; a substance very like an inorganic, but still essentially an organic, compound.

Thus, in studying organic chemistry, we have to investigate—first, the primary organic compounds found in animal and vegetable structures recently killed; and, secondly, the secondary organic compounds produced by their first decomposition before their elements are returned to the sway of inorganic rule. Now, some of these secondary organic proximate principles may be artificially produced, and those that are solid take on the crystalline form. It is probably owing to this that it has been thought possible to artificially construct organic principles. Many of these secondary organic principles are quite unconstructable by art. They are all more or less liable to decay, and when decayed their elements obey altogether precisely those laws noticed in Books I. and II.

There is yet a third class of organic compounds, formed by the decomposition usually augmented by art, if not altogether produced by it, of primary organic compounds belonging to the vegetable* kingdom, and to that class of them hereafter to be noticed, called saccharine. The production of alcohol from the decomposition of sugar is the best example of this class. None of these can be synthetically constructed.

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* Nearly exclusively so.

Thus, in studying organic chemistry, while the elements present are the same as those that have been described under inorganic chemistry, and which indeed were once parts of inorganic masses, as they will be again, we have to investigate the composition and nature of the principles of compound bodies; first, those found in the structures of animals and plants that were recently performing intense vital functions; second, those produced by the spontaneous decomposition of such compounds that usually contain nitrogen; and, third, those produced by the decomposition, generally artificial, of such compounds, and which belong to the saccharine kind.

There are also two complex substances—the atmosphere and water—that are more conveniently studied under the head of organic chemistry.

Before proceeding farther, however, in the study of organic chemistry, it will be necessary to shortly consider,—1. The theory of Compound Radicals; 2. The doctrine of Catalysis; and, 3. The general mode of managing the Analysis of Organic Bodies.

1. *Compound Radicals.* Two elements may unite together and form, as it were, a single atom, or at any rate constitute a compound which behaves like a single atom, and forms unions with other bodies. Thus, there is a substance called ethyle, each atom

of which consists of four of carbon and five of hydrogen, and has the formula ($4C + 5H$). This unites with oxygen, forming an oxide ($4C + 5H$) + O, or ether, as it is commonly called. This oxide may assume water, and become the hydrate of oxide of ethyle ($4C + 5H$) + O + (HO), or alcohol. In organic chemistry such compounds are called compound radicals. When they resemble metals in their mode of behaviour, as is the case with this ethyle, they are often called salt basyles. When they resemble chlorine, bromine, &c., in their alliances, and form acids with oxygen, which form salts with metallic bases, as is the case with cyanogen, for instance, they are called compound salt radicals.

2. *Catalysis.* If we boil starch ($12C + 10H + 10O$) with diluted sulphuric acid, it (the starch) is converted first into dextrine, then into gum, then into cane sugar, and lastly into grape sugar ($12C + 12H + 12O$). And yet when we come at the end of the process to examine the sulphuric acid, we find it undiminished in quantity and unaffected in quality. Or, if we add a little ferment to a solution of sugar, the sugar is converted into alcohol and carbonic acid, although the ferment itself is noways decomposed. These and analogous phenomena are certainly not owing to common affinity, but to some other power. And as when one body is decomposed by another, in consequence of its superior affinity, the decomposing body unites with one element of the body decomposed, and the other element is set free, and we have what is called *analysis,* so Berzelius proposed to call such decompositions as we are now considering, and

in which the substance that causes the decomposition is itself in noways altered, operations of catalysis.

This power of catalysis is believed to be very much of a mechanical nature. The catalytic body is generally in a state of decomposition, and its particles in a state of movement; and this tendency to movement seems somehow or other communicated to the body with which it is in contact. The whole doctrine of catalysis is, however, very obscure, and connected with abstract speculations, which it would be improper here to enter into.

3. *Organic Analysis.* The analysis of organic matter is a very delicate and difficult process; and a very short account of the general manner in which it is conducted is all that can be attempted here. The manner in which the carbon, hydrogen, nitrogen, and oxygen of an organic body are determined will be first stated, and then an account of the manner followed in analysing a soil (or a güano), although this belongs properly to inorganic chemistry.

One process is followed for determining the quantity of carbon and hydrogen, and another that of nitrogen.

The former of these consists in adding to the organic substance as much oxygen as will convert all the carbon into carbonic acid and all the hydrogen into water, and in taking care that the supply of oxygen is so graduated, and that these compounds are formed so gradually, that they may be accurately collected. The process followed and the apparatus used are those described by Liebig.

The substance employed to communicate oxygen is usually (although in special circumstances other bodies rich in that element are preferable) black oxide of copper. The apparatus employed are a combustion tube (*fig.* 93.) made of hard white Bohemian glass, with a bent point, which is sealed; it is about sixteen inches long, and half an inch in diameter; another tube (*fig.* 94.), with a bulb, which fits at its smaller end *a* by means of a cork, into the open end of *fig.* 93.; and at its other end *b* a cork is placed, into which is fitted a small tube, a potassa bulb-tube (*fig.* 95.) which consists of a tube of glass in which five bulbs are blown; the three interior ones pretty close, and communicating freely together, but the two external ones being separated from the others by two inches of tube and a furnace (*fig.* 96.) of iron twenty-four inches long, and in which charcoal is burnt. In practice other articles are necessary, but these will suffice to indicate the principle.

Fig. 93.

Fig. 94.

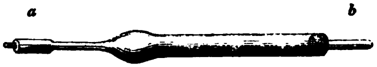
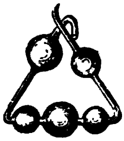


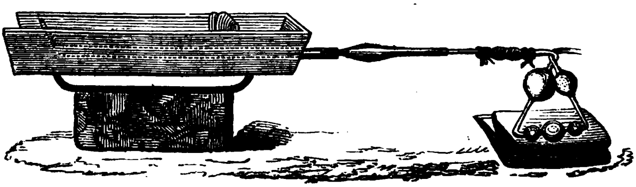
Fig. 95.



Into the combustion tube (*fig.* 93.) is first introduced as much oxide of copper as will occupy about two inches of the bottom end of the tube. Then as much oxide of copper as will fill about six inches of the tube is well rubbed in a mortar with the substance to be analysed (we are assuming it to be a solid), and when incorporated the mixture is to be introduced into the tube, and then some more oxide of copper is put in. The whole is gently shaken, so as to make it fall from the top, and leave a little vacant space between the top of the materials and the upper inside of the tube.

The bulb of the smaller tube (*fig.* 94.) is then filled with chloride of calcium, a little cotton wool being placed at both *a* and *b*. It is then attached to the combustion tube by means of the cork, and by its other end it is connected to the potassa bulb-tube (which is filled with the solution of potassa) by means of a piece of caoutchouc. The combustion tube is then placed in the furnace, in which charcoal is burned. Several little manipulations are necessary, all of which may be omitted here. In *fig.* 96. is a representation of the whole apparatus fastened together, and the combustion tube in the furnace.

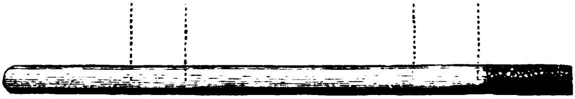
Fig. 96.



The oxide of copper parts, under the influence of heat, with its oxygen, and this element combines with the carbon and the hydrogen of the substance under investigation, and forms water and carbonic acid. All the water is absorbed by the chloride of calcium, and the increase of weight of it indicates how much water has been added to it. In like manner the potassa absorbs all the carbonic acid, and the increase of weight of this potassa bulb-apparatus tells the operator how much carbonic acid has been obtained in the investigation. The quantity of water and carbonic acid obtained being known, it is of course easy to calculate the quantities of carbon and hydrogen that the substance analysed contained.

To ascertain the quantity of nitrogen a combustion tube sealed at the end, but not pointed (the use of the point as a matter of detail is purposely omitted), as in *fig.* 97., is employed. Next the sealed end is placed a quantity of carbonate of copper, then pure oxide of copper, then a mixture of the matter to be investigated and oxide of copper, and then in front of all a quantity of minutely divided metallic copper. A tube is fastened to the end where the copper is, which passes into a mercurial pneumatic trough, and heat is then applied to the closed end of the tube. The carbonate of copper is first decomposed, and the carbonic acid driven off, and this gas sweeps through

Fig. 97.



the apparatus and expels what air is mixed up with the ingredients; but care must be taken to keep at least half of the carbonate of copper undecomposed. The heat is then applied to that portion of the tube containing the metallic copper and the mixture, and the nitrogen of the substance examined is thereby driven from its combinations. Heat is next applied to the tube where the remaining carbonate of copper is, and the carbonic acid drives out the nitrogen into a receiver in the trough, just as before it had expelled the air. This receiver contains a strong solution of potassa, which absorbs the carbonic acid, and the nitrogen that is left can then be measured or weighed.

The use of the metallic copper at the open end of the tube is this;—during the process of decomposition a portion of the nitrogen evolved combines with some oxygen and forms nitric oxide. The red-hot metallic copper, however, at once decomposes this, and appropriates its oxygen, and pure nitrogen is evolved.

When the organic substance to be examined contains an ash of sulphur, chlorine, &c., it is deprived of such by means of nitric acid.

To determine the quantity of oxygen, the plan now commonly followed is to subtract the ascertained quantities of the other elements from the full weight. Its quantity may, however, if desired, be directly valued; but there is no occasion here to detail the process.

An analysis of a soil, at least when it is made not for the purpose of determining the state of its humus, and the quantities of carbon, oxygen, and hydrogen that it contains, but in order to ascertain its inorganic constituents, belongs more to Book I. than to here. Still it is most convenient in this place to give a short abstract of the method pursued by chemists in analysing a soil (or a manure, &c.).

First, the soil is heated up to nearly 400°, to drive off the water. A hundred grains of it is then accurately weighed, placed in a platinum crucible, and exposed to the full heat of an Argand lamp. This drives off all the humic acids, and the loss, after this operation, in the hundred grains, indicates all the organic matter that the specimen contained.

Or the humic acids that are at all soluble may be obtained by decomposing the apocrenate of lime, of ammonia, &c., by carbonate of soda, and adding to the solution of apocrenate of soda, hydrochloric acid, when the organic acid is thrown down, and may be dried and weighed.

To ascertain the *kind* of soluble saline matters contained in a soil, a portion of it must be well boiled, and the solution of it tested as follows:—

a. Solution of nitrate of baryta is added. If a white precipitate is thrown down which does not disappear on the addition of nitric acid, the soil contains sulphuric acid, and the precipitate is sulphate of baryta. If a white precipitate is thrown down when the nitrate of baryta is added, and which disappears when nitric acid is added, the soil contains sulphuric acid, and the precipitate is carbonate of baryta. In this latter case, when the nitric acid is added the carbonic acid is discharged with effervescence.

b. If a solution of nitrate of silver be added, and a white precipitate fall down which is insoluble in pure nitric acid, and soon becomes black by exposure to light, we know that there is chlorine.

c. If a solution of oxalate of ammonia be added, and a white precipitate, or rather cloud, be the result, we are told that lime is present; the cloud being owing to the formation of oxalate of lime.

d. If a solution of caustic ammonia be added, and a pure white gelatinous mass be thrown down, we are informed that it is owing to the presence of either alumina or magnesia, or to a mixture of these (alumina and magnesia being precipitated from their combinations by ammonia, and both being of a white colour). Magnesia, however, is soluble in an excess of ammonia, and, therefore, by adding more ammonia we can obtain an idea whether it is exclusively magnesia, exclusively alumina, or a mixture of the two.

If the magnesia or alumina have a brown tinge, we infer the presence of iron; which substance is also precipitated from its salts by ammonia.

e. If we throw down the magnesia and alumina from a portion of the solution, and separate them by the filter, and then throw down the lime by oxalate of ammonia, and in like manner remove it by filtration, then evaporate to dryness, and expose the residue to a red heat to evaporate the ammonia, and next try if a soluble residue be left, we may conclude, if such be the case, that the soil contains either potassa or soda.

If we dissolve this residue in water, and add tartaric acid, if potassa be present its presence is at once indicated by the white powder of bitartrate of potassa; or if we add bichloride of platinum, if there be potassa, the yellow bichloride of potassium and platinum is thrown down. If the solution that is left behind be evaporated, and a solid residue left, then the soil contained soda.

f. If we add to another portion of the solution a little caustic potassa, if ammonia be present it is liberated, and may be detected by the smell; or if it is in very small quantity, by its making red litmus paper blue.

g. If a portion of the solution be evaporated to dryness, and if the dry mass be put into a test tube with a little hydrochloric acid, if a nitrate be present, red fumes of nitrous acid will be evolved.

h. We can ascertain the presence or absence of phosphoric acid as follows—we add ammonia to a portion of the solution, to precipitate the alumina, magnesia, and iron, and remove these by the filter; if we then add chloride of calcium and no precipitate follow, then no phosphoric acid is present. But if phosphoric acid be present, phosphate of lime is immediately thrown down. This may be dissolved in nitric acid, the mixture then neutralised with ammonia and acetate of oxide of lead added, upon which phosphate of lead, which may be distinguished by its physical characters, is precipitated.

But we may not only ascertain the quality but the quantity of the different inorganic constituents of a soil, &c. Thus,—

a. To determine the quantity of sulphuric acid, weigh the dried sulphate of baryta that is thrown down, and every hundred grains of it are equal to about thirty-four of sulphuric acid.

b. To determine the quantity of chlorine, weigh the dried precipitate of chloride of silver, and every hundred grains of it contain nearly twenty-five of chlorine.

c. To determine the quantity of lime, take the oxalate of lime that is precipitated, burn it, and convert it into carbonate of lime, every hundred grains of which contain about forty-four of lime.

d. To estimate the quantity of oxide of iron and alumina, the operator proceeds thus,—he adds ammonia, which, if magnesia, oxide of iron, or alumina be present, throws them down. Hydrochloric acid is added to dissolve this precipitate, and then a little nitric acid, and the liquid heated, the effect of the nitric acid aided by heat being to convert the iron into the peroxide. A precipitate again falls down, which is peroxide of iron and alumina; this is collected, and again dissolved in hydrochloric acid. A solution of caustic potassa throws down both the alumina and oxide of iron, but if added in excess redissolves the alumina, and leaves only the oxide of iron, which may be collected upon a filter and weighed.

In order to determine the quantity of alumina, the above solution of it in potassa is taken, and the potassa neutralised by hydrochloric acid. By again adding ammonia the alumina is again thrown down, and may be dried and weighed.

e. To estimate the quantity of magnesia, potassa, and soda, the operator, by adding successively nitrate of baryta, oxalic acid, and ammonia, precipitates the sulphuric acid, the lime, the oxide of iron, and alumina. He then evaporates to dryness, and exposes the product to a red heat. This dry mass he dissolves in water, adding, if necessary to complete the solution, a little hydrochloric acid. To this solution a little red oxide of mercury is added, and the fluid is again evaporated to dryness and heated. Any chlorine that it contains combines with the mercury, and the bichloride of mercury thus formed is sublimed. There is nothing left now but potassa and soda; the two, however, combined with chlorine and magnesia. The two first are soluble in water, the last not so. By merely adding water the potassa and soda are dissolved away, and the magnesia that is left may be dried and weighed.

To estimate the quantity of soda and potassa, the solution is evaporated to dryness, and the dry mass that is obtained weighed. It is then dissolved in a little water, and a solution of bichloride of platinum added, upon which the chloride of potassium and platinum are formed. The solution by a very gentle heat is again evaporated, nearly to dryness, and weak alcohol added. The alcohol dissolves the chloride of sodium, leaving the double chloride of platinum and potassium as a yellow powder. This is dried and weighed, and every hundred grains of it denote about twenty of potassa. Then the loss of the original weighing is taken, which indicates the quantity of chloride of sodium, and every hundred grains of chloride of sodium are equivalent to fifty-three of soda.

f. To estimate the ammonia. If ammonia be present, it will be associated with potassa and soda in the preceding analysis. Caustic baryta may be added to make the solution alkaline, and the mixture then be distilled. Hydrochloric acid is then added, and next bichloride of platinum. Of the yellow powder that is thrown down, every hundred grains represent about eight of ammonia.

g. To estimate the phosphoric acid. If phosphoric acid be present it will be thrown down in *d,* along with the alumina and oxide of iron, by ammonia. This precipitated mixture is heated along with carbonate of soda, and the fused mass treated with cold distilled water, until everything that is soluble is taken up. The filtered solution is then treated with hydrochloric acid, ammonia added, and next a solution of chloride of calcium, upon which phosphate of lime is precipitated. Every hundred grains of phosphate of lime contain forty-eight of phosphoric acid.

CHAP. II.

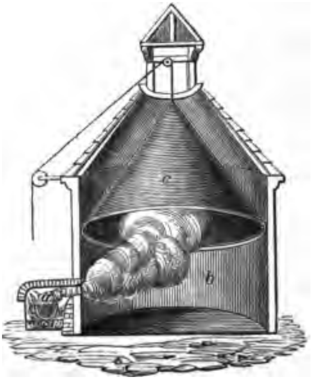
CARBON AND ITS COMPOUNDS.

CARBON is an elementary principle that occurs very abundantly. Originally, and in the very early days of the world, before animals and plants were called into being, it was probably all contained in the atmosphere, and that in combination with oxygen. At present all the carbon of the globe is either contained in animal or vegetable structures, or if it appear in an inorganic state it has evidently been derived from organised structures. Thus the immense mass of coal which is so rich in carbon, is merely the remains of compressed trees; and the carbonates of lime, known as marble, chalk, &c., are but the *débris* of the structure of myriads of shell fish. Even the diamond, that is the purest form of carbon, yields on burning a trace of inorganic matter, thereby indicating its origin from the decomposition of organic matter; and the carbonic acid present in the air is, now as we know, an exhalation from the breathing apparatus of animals.

In order to obtain carbon, animal or vegetable substances are exposed to a very high temperature, in closed vessels. The kinds of carbon thus produced, however, differ very much. Coal treated in this manner gives *coke*, which is carbon mixed with the inorganic constituents of the trees that have formed the coal; *lampblack* is the carbon of resin; *ivory black* of bones; and the common *charcoal* of the shops is wood deprived of its oxygen and hydrogen.

All these sources of carbon consist mainly of oxygen, hydrogen, and carbon. If they be set on fire in the open air they are entirely converted into water and carbonic acid. If, however, the supply of air be limited, the affinity of the oxygen for the hydrogen so far exceeds its affinity for the carbon that no carbon is consumed until all the hydrogen present has united with oxygen and formed water. In making wood charcoal the billets of wood are piled together, and covered with sods; the wood is lit at the top, and the combustion proceeds downwards. To manufacture lampblack (*fig.* 98.) the air is more elaborately excluded. *a* is an iron pot, containing boiling pitch. The furnace that keeps it boiling is vaulted over, so

Fig. 98.



that the vapour passes into the chamber *b*. Into this chamber a very small quantity of air only is allowed to enter. *c* is a moveable cover of coarse linen, through which the draught passes. When the boiling pitch takes fire the hydrogen of it alone burns, and the carbon is deposited as a very fine powder upon the cover and the sides of the furnace.

The preparation of animal charcoal, or bone black, will be mentioned in Chap. VII., under the head hydrochlorate of ammonia.

These varieties of charcoal are possessed of some very remarkable properties, which the various forms however of it possess in various degrees. It has a strong tendency to unite with colouring and odorous substances. The lampblack possesses this property in the greatest degree, and a form of it made by calcining hoofs, &c., with carbonate of potassa, owing to the extreme state of comminution in which it is obtained, is still more efficient in this respect. In the arts this property of charcoal is put to use in purifying sugar, depriving water in barrels at sea of any decomposing animal matter they may contain, &c.

Charcoal that has been used for this purpose may be ignited, but its deodorising power is quite lost. The reason is a mechanical one,—the colouring matter that it contains fusing with the heat, and thereby destroying or diminishing its porosity.

Charcoal, too, possesses the property of absorbing a large quantity of gaseous substances at ordinary temperatures, and of parting with them again when heated. It absorbs very different amounts of different gases. Thus an inch of box-wood charcoal absorbed during the space of from 24 to 36 hours—

Ammoniacal gas -	- 90 times its volume,
Sulphuretted hydrogen	- 81 „
Sulphurous acid -	- 65 „
Carbonic acid -	- 35 „
Oxygen - -	- 9 „
Nitrogen - -	- 7 „
Hydrogen - -	- 1.7 „

Charcoal, as obtained from wood, is hard and brittle. It conducts heat very slowly, but electricity well. It is insoluble in water, in the acids (save the nitric), and in alkalies. If exposed to the most intense heat, provided air be excluded, it remains quite unchanged. In the open air it burns slowly, in oxygen its combustion is more lively, and in both cases (if the carbon be pure) there is no smoke, no flame, and no residue. In both cases, also, carbonic acid is formed.

The atomic weight of carbon is 6, and its symbol C.

The compounds of carbon, described in this section, are as follows:—

					Formula.
1.	*Carburetted hydrogen* - -	Carbon - 1 atom	6+Hydrogen - 2 atoms	2= 8	C+2H.
2.	*Olefiant gas* -	Carbon - 2 atoms	12+Hydrogen - 2 atoms	2=14	2C+2H.
3.	*Carbonic oxide*	Carbon - 1 atom	6+Oxygen - 1 atom	8=14	C+O.
4.	*Carbonic acid* -	Carbon - 1 atom	6+Oxygen - 2 atoms	16=22	C+2O.
5.	*Oxalic acid* -	Carbon - 2 atoms	12+Oxygen - 3 atoms	24=36	2C+3O.
6.	*Sulphuret of carbon* - -	Carbon - 1 atom	6+Sulphur - 2 atoms	32=38	C+2S.
7.	*Chlorides of carbon* - -	Various.			
8.	*Carburet of potassium.*				
9.	*Principal carborates.*				
10.	*Principal oxidates.*				

1. Carburetted Hydrogen.

This should be called the dicarburet of hydrogen. It is formed abundantly in stagnant pools by the decomposition of dead vegetable matter, and also often in coal mines from the decomposition of coal in contact with moisture. As, when mingled with air, it forms a very explosive mixture, it is often called by the miners fire-damp.

It is a colourless, tasteless, inodorous gas, scarcely soluble in water, and is not a supporter of combustion. It burns, however, with a strong yellow flame, and gives out considerable light. As just mentioned, when mixed with air or oxygen, it explodes on coming into contact with a light.

2. Olefiant Gas.

This name is given to it on account of its forming an oily liquid with chlorine. It is also often named heavy carburetted hydrogen. Although heavy when compared with the compound previously described, it is rather lighter than air. The peculiarity of its composition renders it difficult to distinguish it according to the regular plan of chemical nomenclature, and it has been proposed to call it the $\frac{2}{2}$ carburet of hydrogen.

It is obtained, but in a very mixed and impure state, from the distillation of coal, but it may be obtained pure by depriving alcohol of 2 atoms of water by means of sulphuric acid. Supposing an atom of alcohol consist of O 4C + 6H + 2O, by subtracting 2 atoms of water, or twice (H + O) 2 atoms of olefiant gas will clearly be produced.

It is a colourless and transparent gas, little soluble in water, and supporting neither combustion nor respiration. It burns with a brilliant white light. Mixed with a due proportion of oxygen it forms a mixture violently explosive on the approach of flame.

The common illuminating gas used for lighting streets and dwellings is essentially a compound of heavy and light carburetted hydrogen. We shall again have occasion to refer to it, but this appears to be the most suitable place for some general remarks upon flame.

Flame. By flame is meant a vapour or gas heated to that pitch of intensity that, besides evolving heat, it gives out light. The amount of heat necessary to produce flame varies much in different substances. Phosphuretted hydrogen, as we have seen, flames at an ordinary temperature, phosphorus at a temperature of 120°, and sulphur at 300°, while carburetted hydrogen does not unless brought to a bright red heat.

It is, however, to the combustion of compounds of carbon and hydrogen that all our artificial illumination by fires, by candles, by lamps, or gaslights, is owing, and it is to these flames that the following short description refers.

If we inspect the flame of a candle, we see in the interior, and just above the wick, a spot that when contrasted with the luminousness of what is going on around it, seems quite dark. It is marked *a* in *fig.* 99., and may be named the *area of no combustion.* Around it is a very luminous cone, marked *b*, and from which the greater part of the light proceeds, and which may be called the area of partial combustion; and on the outside is another cone of luminous matter, *c*, which is exceedingly hot, but from which much less light proceeds than from *b*, and this may be termed the area of complete combustion.

The area of no combustion consists of a mixture of the two carburetted hydrogens, driven off the wick from the decomposition of the wax or tallow. If, as in *fig.* 100., a glass tube, open at both ends, have one end introduced into this area of no combustion, these gases may be drawn off and ignited at the end.

Fig. 99.

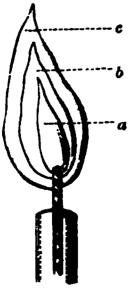


Fig. 100.

As before mentioned, if carbon and hydrogen are exposed to a high temperature, with but a little supply of oxygen, the hydrogen takes it all and forms water. This is what occurs in the middle cone or area of partial combustion. If a solid substance that can endure the heat be put into this, the carbon is rapidly deposited upon it in the form of soot or lampblack.

As the carbon is separated here, however, the intense heat makes it of a white heat, and this is the reason that this middle cone is so very luminous. The flame of hydrogen gas, as will be remembered, is very far from being a bright one, but the heated pieces of carbon in it evolve light like the lime does in the lime-ball light.

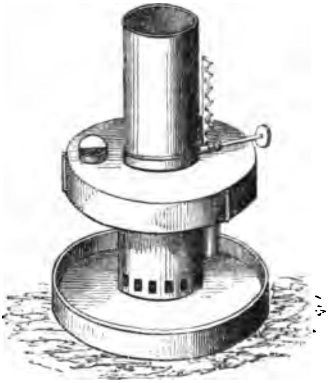
In the outer cone or area of complete combustion the carbon, that has been shining so brightly in the middle cone, meets with oxygen, and becomes converted into carbonic acid.

By a little contrivance the carbon and hydrogen from a common gas jet may be made to ignite simultaneously, in which case the light evolved is very trifling.

Flame, in fact, consists of particles of gaseous matter heated to a white heat. Hence we can understand that when a combustible, as well as the product of its combustion in oxygen (or its oxide) is solid, its flame will be brilliant; but that when the reverse is the case, it will be feeble. For example, iron and its oxide are both solid, and when iron is burned great light is evolved, and in like manner both phosphorus and its oxide, phosphoric acid, are solid; and we had occasion to notice the brilliancy of its flame. On the other hand, sulphur, although solid itself, becomes a gas when oxidated, and its flame is feeble; while hydrogen, which is a gas to begin with, and the product of the combustion of which is gaseous also, is scarcely luminous at all.

In an ordinary candle only a portion of the carbon that is exposed to this heat combines with oxygen to form carbonic acid, and another portion is given off as soot. In applying heat by means of flame to glass vessels it is desirable to consume all of the carbon, in order to prevent the flask being soiled. The construction of the Argand lamp (*fig.* 101.) insures this.

Fig. 101.



In it a current of air is sent up through the middle of the flame, and thus furnishes a sufficient quantity of oxygen to oxidise all the carbon, and prevent any uncombined carbon or smoke from being given off. In large towns contrivances based upon the same principle are employed for consuming the smoke from factories.

Connected with the subject of flame is the blowpipe, formerly merely employed as a small blast by the jewellers, but now a very important philosophical implement. *Fig.* 102. represents a blowpipe, such as is commonly used. It is a tube usually formed of copper, with a mouth-piece, *a*, and a nozzle of small bore, *b*, through which a continuous stream of air may be forced across the flame of a lamp. A proper lamp for the purpose is figured in *fig.* 103., and a stream of air is supposed to be impinging upon the flame from a blowpipe. The air is forced into the area of no combustion, and hence oxidation goes on both in the centre of the flame and on the outside of it.

Fig. 102.

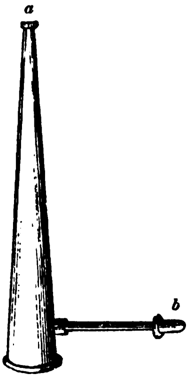
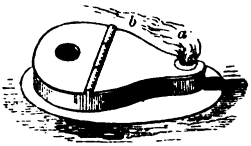


Fig. 103.



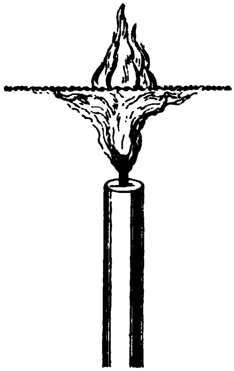
If the blowpipe flame be examined, two cones will be observed, one which is inner and blue, marked *a*, and the other outer and yellow, and marked *b*. The former of these is often called the reducing, and the latter the oxidating flame. The first of these expressions is strictly correct, for the amount of white hot carbon that it contains is so great that it immediately combines with the oxygen of a metallic oxide introduced into it, and the metal is obtained in its metallic or uncombined state. The term oxidising flame is not so correct; for although a metal placed near it is oxidated, it is not the flame that does it, but the intense heat; and, in fact, to insure its oxidation it must be carefully held a little in front of it.

By means of the blowpipe every species of mineral may be recognised and distinguished from other minerals.

Another very important instrument connected with the subject of flame is the safety lamp.

Owing to the great rapidity with which metals conduct away the heat that they receive, it is found that a piece of wire gauze, having its orifices sufficiently minute, arrests the temperature of flame so much as actually to extinguish it. Thus, if a piece of wire gauze be held over the flame of a gas jet, or of a candle, as in *fig.* 104., the flame is immediately arrested at the lower surface of the gauze. The gas and air pass through readily enough, and if the gas and air be allowed, as in *fig.* 104., to pass through the gauze and ignited above, they burn readily enough; and in this case, although the inflammable matter is lying between the jet and the bottom of the gauze, the flame never passes downwards, its heat being so rapidly carried away by the metal. A common experiment, which very well illustrates this, is to place a piece of camphor upon the metallic gauze, and to hold it over a lamp. The camphor soon begins to vaporise and melt, but as it does the latter a portion of the fluid camphor passes through the gauze. This immediately takes fire, and a sheet of flame covers the lower surface, while the camphor above vaporises without flame.

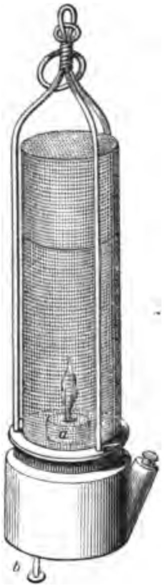
Fig. 104.



As stated above, carburetted hydrogen is exhaled in coal mines, and forms with air or oxygen a mixture that is violently explosive on the approach of a light. Very dreadful accidents have often happened in coal mines from this cause, and the detonation produced is often so strong as to destroy almost all in the pit; and even if any are so fortunate as to escape the first violence of the shock, they are usually smothered, owing to the immense quantity of carbonic acid produced by the explosion.

The safety-lamp effectually preserves the miner from these calamities. *Fig.* 105. is a representation, as when in use, of this valuable apparatus. *a* is an oil-lamp, only differing from a common one in having a brass wire with one end at the wick, and the other outside at *b*, and the use of which is to allow the wick being trimmed without opening the lamp. On the top of this lamp is secured a wire gauze cover. This gauze must contain about 22 orifices to the square inch. Supposing this lamp to be lighted, and the gauze cover carefully screwed on, and the whole put into a detonating mixture of carburetted hydrogen and air or oxygen, no explosion occurs. The mixed gases indeed enter the lamp through the meshes, and are consumed around the wick, but the flame that is in the inside of the lamp cannot pass through to the outside so as to kindle the inflammable mixture.

Fig. 105.



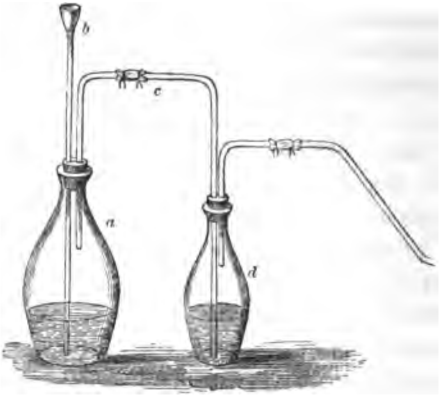
The safety-lamp of Davy only fails in giving security when it is placed in the midst of a very rapid current of the detonating mixture. This may so hurry the inflamed gas in the inside through the lee side of the lamp, as to explode the surrounding gases. Davy's remedy for this was a moveable tin shield, and other contrivances have been suggested that seem effectual.

3. CARBONIC OXIDE.

This compound may be prepared by passing carbonic acid through red-hot charcoal, upon which the acid parts with one atom of its oxygen. If wanted in the laboratory, however, it is always obtained by the following simple process:—

a, fig. 106., is a flask containing oxalic acid; *c* is a

Fig. 106.



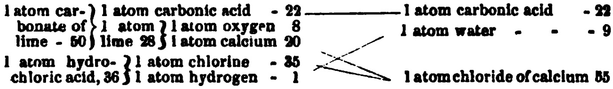
tube leading from it, and going to the bottle *d*, partly filled with solution of potassa; *b* is a funnel through which sulphuric acid is poured. The action that takes place is very simple. Oxalic acid cannot exist except in combination with water, and the sulphuric acid deprives it of its water. The acid is composed of two atoms of carbon and three of oxygen, and, losing its own distinctive character, is naturally resolved into carbonic acid and carbonic oxide. As the former of these passes into the potassa solution it is immediately combined with it, forming carbonate of potassa, while the carbonic oxide issues through the tube leading from *d*, and may be collected over water.

It is a gas without colour or odour; it is not a supporter of combustion itself, but burns with a pale-blue flame, and forms carbonic acid. It is this gas that produces the blue flame (purple when red cinders are behind it) seen on the top of a clear fire. It not only does not support respiration, but is positively poisonous, and one of the deleterious ingredients in the fumes of burning charcoal.

4. CARBONIC ACID.

Carbonic acid exists in the air as the product of respiration and combustion. Combined with earthy and metallic oxides it forms a very abundant class of salts or carbonates. It is generally produced during the decomposition of vegetable substances, and is rapidly evolved during the process of vinous fermentation.

In the laboratory it is prepared by the action of hydrochloric acid upon carbonate of lime. The following table represents the decomposition that takes place:—


1 atom carbonate of lime - 50
1 atom carbonic acid - 22
1 atom lime 28
1 atom oxygen 8
1 atom calcium 20
1 atom hydrochloric acid, 36
1 atom chlorine - 35
1 atom hydrogen - 1
1 atom carbonic acid - 22
1 atom water - - - 9
1 atom chloride of calcium 55

At ordinary temperatures and pressures carbonic acid is a gas. In this state it is invisible, has a faint odour, and a sharp taste. It is half as heavy again as air. It neither supports combustion nor respiration. It slightly reddens litmus paper.

At a pressure of thirty-six atmospheres at 32° it is a fluid. In this form it is a colourless very mobile liquid. Exposed to the air it evaporates with such rapidity as to produce as much cold as solidifies a portion of it. This solid carbonic acid is a white body in filamentous masses.

Carbonic acid is a very important article of food to plants, and in their organs of assimilation it is deprived of its carbon, which is added to the vegetable structure, and the oxygen is restored to the air. Were it not for this provision of nature, the carbonic acid, driven into the air by the two processes of respiration and combustion, would soon render the atmosphere a deadly poison to animals.

Carbonic acid is known by its action upon litmus paper, its being incombustible and not a supporter of combustion, and by forming with lime a white precipitate soluble in acetic acid.

Carbonates are recognised by parting with their carbonic acid (which may then be tested as just mentioned) when acetic or hydrochloric acids are added to them.

5. Oxalic Acid.

Oxalic acid combined with potassa is an organic compound formed by many plants, and was formerly extracted from the *Oxalis acetosella,* from which circumstance it derives its name.

Oxalic acid cannot be artificially formed by the combination of its elements, but, like some other secondary and tertiary organic compounds, it may be obtained by acting upon some other organic compound. When, for instance, nitric acid is added to sugar, the acid is decomposed and nitrous acid gas is evolved, and the oxygen of the acid that is set free combines with the carbon of the sugar, and oxalic acid is the result.

The properties of oxalic acid are that its crystals are colourless and transparent, their primary form being a right-rhombic prism ; they have an extremely sour taste, powerfully affect litmus paper, and combine with bases. They contain three atoms of water, one of which is basic, and if, as before mentioned, this be taken away by means of sulphuric acid, the oxalic acid is resolved into carbonic acid and carbonic oxide. Oxalic acid is very poisonous.

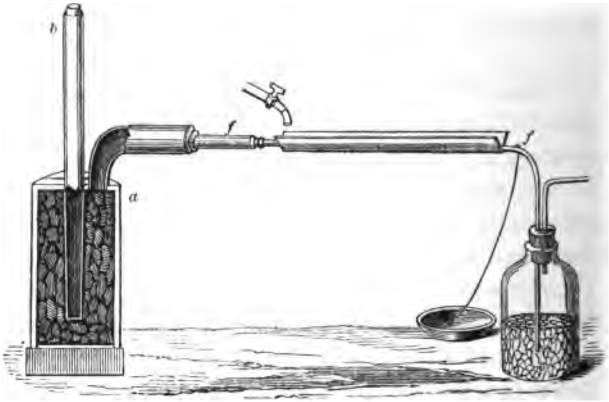
Oxalic acid is recognised by its strong acidity, and by not leaving a carbonaceous matter when heated. A solution of an oxalate gives with lime-water a precipitate (oxalate of lime) that is insoluble in oxalic or any other organic acid.

6. SULPHURET OF CARBON.

This compound clearly belongs to the inorganic department, but its consideration was necessarily deferred until this place. It may be prepared in the following manner :—

The tube *a c* (*fig.* 107.) is filled with bits of charcoal and placed in a furnace. Pieces of sulphur are introduced from time to time at *b*, which is then closed with a piece of cork. The tube is a little inclined, and as the sulphur fuses it runs down upon the ignited charcoal and combines with it. This compound passes as vapour into the long tube *f*, which is covered with a cloth and kept constantly wetted by a small stream of water. It is here condensed, and passes as a fluid into the bottle.

Fig. 107.



Sulphuret of carbon is a liquid without colour, but having a disagreeable, garlic-like smell. It is very volatile, and was formerly called alcohol of sulphur. Its evaporation produces great cold. It is very inflammable, burns with a blue flame, and is resolved into carbonic and sulphuric acids. Heated in contact with a metal, carbon is separated, and a metallic sulphuret formed.

7. Chlorides of Carbon.

There are probably four compounds of chlorine and carbon. The sesquichloride is produced by the action of sunlight upon olefiant gas.

8. CARBURET OF POTASSIUM.

This compound is supposed to exist, but has no been isolated.

9. PRINCIPAL CARBONATES.

a. Carbonate of Potassa. This compound has been called salt of tartar and the mild vegetable alkali. It sometimes, as in ferns, exists ready formed in plants, but it is usually obtained from the acetate of potassa, which is an abundant secretion of all land plants. The trees are burnt, and their carbon, uniting with the oxygen of the air becomes carbonic acid; and this expels the acetic acid from the acetate, the result being carbonate of potassa.

The wood is piled in heaps and burnt, and the mixed product thereby obtained is called *wood ashes.* In America the ashes are mixed with lime, and owing to their colour are termed in commerce *black* ashes. This substance is heated for several hours, and then becomes the *potash* of trade. To make *pearlash* of the shops the combustible materials are burnt in a furnace in which the flame is by a little contrivance made to play upon the surface of the alkali. All these are a mixture of carbonate of potassa, sulphate of potassa, and chloride of potassium, and other minor impurities. The proportion of alkali varies from 60 to 85 per cent., and as the value of different samples depends entirely upon this, it is desirable to be able by an easy operation to determine it. This is done by means of alkalimetry, described in page 81.

For chemical purposes, carbonate of potassa is prepared by heating the tartrate of potassa to redness. The tartaric acid is entirely converted into carbonic acid and charcoal. From this mixture the carbonate of potassa is obtained pure by means of filtration and evaporation.

Carbonate of potassa consists of one atom of acid and one of base. It has a strongly alkaline taste, is slightly caustic, and communicates a green colour to the blue of the violet. It is deliquescent, and dissolves in its own weight of water at 60°. It is insoluble in alcohol.

b. Bicarbonate of Potassa. This is prepared by passing a stream of carbonic acid through a solution of the carbonate, heated up to 100°. On cooling it crystallises in right-rhombic prisms, which are soluble in four parts of cold water, and less of hot.

Its solution may be distinguished from that of the carbonate by adding a solution of bichloride of mercury. The bicarbonate throws down a white, the carbonate a brick-dust precipitate.

c. Carbonate of Soda. As the land plants essentially contain a salt of potassa, so the plants that live in or near the sea contain soda. From these the carbonate of soda, or the mineral alkali as it used to be called, was obtained.

Formerly the seaweeds that were washed upon the shores of the Hebrides were carefully collected, and under the name of kelp, extensively employed in the manufacture of soda. Some plants were sometimes cultivated for the purpose in the neighbourhood of the sea; and these in the mass were named barilla. But at the present time the carbonate of soda of commerce is procured from sulphate of soda, either manufactured for the purpose by adding sulphuric acid, chloride of sodium, or from the refuse sulphate of soda of the chlorine manufactories.

This sulphate of soda is mixed with chalk and carbonaceous matter, and the composition put into a reverberatory furnace. By the action of the sawdust (or whatever carbonaceous matter is employed) the sulphuric acid is decomposed, part of the sulphur is driven off in the shape of sulphuric acid, and a part combines with the calcium of the lime, while the carbonic acid formed by the union of the carbon of the sawdust with the other oxygen of the sulphuric acid unites with soda. The carbonate of soda thus obtained is purified by solution and crystallisation.

Carbonate of soda crystallises in rhombic octohedrons. These crystals are transparent, effloresce, dissolve in twice their weight of water at 60°, and in less than their whole weight at 212°, and their solution has a strong alkaline taste and reaction. They contain ten atoms of water.

Fig. 108.

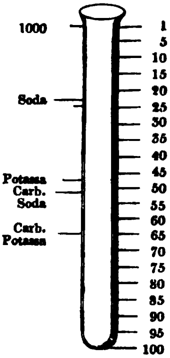


Fig. 108. represents an alkalimeter, an instrument before referred to, as readily indicating the purity, and therefore the commercial value, of the alkalies. It is a glass tube, nine inches and a half long, and three-quarters of an inch in diameter, and sealed at one end. Into this a thousand grains of water are poured, and the place where the surface of the water reaches marked with a diamond. The interval between this and the bottom of the tube is then divided into a hundred parts. Opposite 23·44 soda is marked, opposite nearly 49 potassa, at 54·6 carbonate of soda, and at 65 carbonate of potassa.

A diluted sulphuric acid, having the density of 1·127, and which may be made by mixing one measure of concentrated acid and four of distilled water, is prepared. That is, it is exactly of that strength that when poured into the tube until it reach either of the above four marks, we shall obtain the precise quantity necessary for neutralising 100 grains of that alkali written opposite to it. If this diluted acid be poured into the tube until it reach 65, or the carbonate of potassa mark, we have as much acid as will exactly neutralise 100 grains of carbonate of potassa. If, then, we fill the tube up to 1, each division of the mixture will neutralise just one grain of carbonate of potassa. In examining, therefore, any sample of pearl-ash, &c., 100 grains of it are dissolved in water, and poured into the tube, the acid added, and the mixture tested by litmus paper. Each division of the mixture indicates a grain of pure carbonate.

d. Bicarbonate of Soda. This is prepared by passing a current of carbonic acid through a solution of the carbonate, upon which the bicarbonate precipitates in small opaque crystals.

There is also a native sesquicarbonate, but this cannot be formed at will.

A mixture of carbonate and bicarbonate of soda is sold under the erroneous name of sesquicarbonate.

e. Carbonate of Baryta. This occurs native, and is a very poisonous salt.

f. Carbonate of Lime. The occurrence of this salt in nature, and also the peculiarity of its crystals, have been noticed before. It may be obtained pure by the decomposition of chloride of calcium by carbonate of ammonia. It is insoluble in pure water, but, like silica and other substances, it dissolves in water that contains carbonic acid. It is thus held in solution by most springs in limestone districts, and is deposited when the carbonic acid is expelled by boiling, or by the slower process of exposure to the air.

Carbonate of lime contains one atom of base and one of acid, and no water.

g. Carbonate of Magnesia. This salt occurs native, and is anhydrous. It may be artificially formed by dissolving magnesia in water saturated with carbonic acid. In this case, however, it contains three atoms of water, and is the salt that exists in Murray's solution of magnesia.

If acted upon by hot water this carbonate parts with a portion of its carbonic acid, and the common carbonate of magnesia of the shops is formed. This consists of a compound of carbonate and hydrate, and for commercial purposes is usually prepared by mixing together sulphate of magnesia and carbonate of soda. The precipitate of the magnesian salt that is thereby produced is nearly insoluble in water.

h. Carbonate of Protoxide of Iron. This occurs native, and may be artificially prepared by decomposing sulphate of the protoxide of iron by carbonate of soda. It is then a white powder, which on exposure to the air rapidly absorbs oxygen, and parts with carbonic acid, and in this manner very soon becomes converted into the red oxide.

As the carbonate is an active therapeutical agent, it is desirable to prevent this, and it is found that sugar possesses the power of retarding this change.

Carbonate of iron is soluble in water containing carbonic acid, and in this state of solution it exists in many chalybeate springs.

i. Carbonate of Oxide of Lead. This compound has been known for a long period. It has been called magistery of lead, ceruse, and white lead. It occurs native, and may be formed by decomposing a solution of nitrate of baryta by carbonate of soda.

For commercial purposes (it being much used as a pigment) it is made by exposing sheets of lead to acetic acid in vapour, acetate of oxide of lead is formed, which is gradually decomposed by the carbonic acid of the air, and the carbonate is produced.

10. Principal Oxalates.

a. Oxalates of Potassa. There are three oxalates of potassa, interesting to the chemical student as being the bodies pointed out by Dr. Wollaston as furnishing a remarkable proof of the doctrine of multiple combinations.

The neutral oxalate of potassa may be formed by neutralising oxalic acid with carbonate of potassa. It crystallises in rhombic prisms, has a bitter taste, and is soluble in water, but not in alcohol.

The binoxalate of potassa exists naturally in sorrel, and is hence often called salt of sorrel. It may be artificially formed by adding more oxalic acid to the neutral oxalate. It crystallises in oblique rhombic prisms, is soluble in forty parts of cold and six of hot water, and has a sour and saline taste. It is poisonous.

The quadroxalate of potassa is formed by adding to the neutral oxalate three times as much oxalic acid. It is sold in the shops as salt of lemons, and is used to take ink-stains from table-cloths, &c. This last is done by its forming with the gallate of iron a double salt that is soluble.

b. Oxalate of Lime. This exists abundantly in many lichens, and may be artificially formed by adding oxalate of ammonia to any soluble salt of lime. It falls down as a white precipitate, quite insoluble in water, and oxalic acid is therefore the test employed for lime.

CHAP. III.

SACCHARINE PROXIMATE PRINCIPLES.

THESE substances occur very abundantly in plants; but, with one exception, are never formed in animal structures. They are truly organic compounds, and cannot be synthetically constructed by bringing their elements into juxtaposition by art. They are formed by the power of vitality, and by it alone. In living structures it would appear that the same power of vitality can very readily transform one into another; and some of these *transformations* may be brought about by art.

All the saccharine proximate principles consist of carbon, oxygen, and hydrogen; and the two latter are always in the same proportion as they are in water. Hence the only difference in chemical constitution between them consists in the number of atoms of carbon that each atom of them contains; and hence we can consequently easily understand how readily they are transmuted one into another.

I. STARCH AND ITS VARIETIES.

Starch probably occurs in every plant, and in almost every part of it except the very young portions, as the radicles. Indeed, it is probable, as will be subsequently seen, that the starch is the first organic compound formed by the vital powers of the plant out of the inorganic carbon, oxygen, and hydrogen taken in at the root and leaves. Accordingly, it is the basis of the nourishing fluid that circulates through the plant, or of sap, and in seeds and tubers. Starch is abundantly laid up as a store of nutriment for the young embryo.

Four varieties of starch exist:—

a. Common Starch. When the grain of corn is mixed up into a dough with water, and this dough washed on a linen cloth with water, a whitish turbid fluid comes over, which, if allowed to stand, deposits a white powder, which is wheaten starch. In like manner, the pith of the sago palm, if similarly treated, deposits an analogous powder, which, when dried, constitutes the sago of the shops; the potato gives potato-starch; the Maranta tree, arrowroot; and the Manihot, tapioca.

All these look a little different, owing principally to the manner in which they are prepared; but they are exactly identical in chemical composition and properties. Starch is colourless, tasteless, and without smell; perfectly insoluble in cold water, but dissolving readily in hot, and forming in this manner a solution which gelatinises on cooling. It gives a blue colour immediately on being touched with a cold solution of iodine. This is owing to the blue iodide of starch being formed.

Each atom of starch consists of 12 atoms of carbon, 10 of oxygen, and 10 of hydrogen.

b. Inuline. In the roots of the dahlia, the dandelion, and other plants, a peculiar kind of starch is found, to which the name of inuline is given. Like common starch this inuline is insoluble in cold and soluble in warm water, but, unlike starch, it does not form a jelly when its solution in boiling water is allowed to cool, but falls down as a white powder, and it gives a yellow colour instead of a blue with iodine. Its composition is the same as that of common starch; or, perhaps, each atom contains 12 atoms of carbon, 9 of oxygen, 9 of hydrogen, and 1 of water.

c. Lichenine. This variety of starch is found in Iceland moss and other lichenous plants. Like common starch it forms a gelatinous mass, when cooled, from its solution in hot water; but, instead of giving a blue colour with iodine, it strikes a greenish tint. In chemical constitution it is exactly analogous to common starch.

d. Dextrine. This substance is obtained from starch in three manners:—

1st. As in natural vegetation (which may be imitated by making a grain artificially germinate, as is done in malting), by contact with the albuminous principle diastase, hereafter to be noticed.

2nd. By heating starch in an oven up to 300°. Prepared in this manner, it is sold and used in the arts under the names of starch-gum and British gum.

3rd. By the action of diluted sulphuric acid at a moderate temperature upon it.

It is also in the economy of plants readily obtained from starch, and also in the stomachs of animals.

In chemical composition it is entirely identical with the starch in which it originates; but it differs from that substance in being entirely soluble in cold water. It is also readily converted into the saccharine nutritious proximate principle sugar; and, before starch can afford nutriment (all nutriment must be soluble in water) to either embryo plants or perfect ones, it must be transformed into dextrine or undergo a still farther transformation from dextrine into sugar.

II. CELLULOSE AND ITS VARIETIES.

This constitutes the greater part of the structure of the older portion of plants. Thus the stems of dried grasses, clovers, or corns contain a large proportion of it; and a modification of it called lignine constitutes the skeleton as it were of trees. It is cellulose that forms the tubes and cells of vegetable tissues, and which constitutes the fibres of cotton, linen, hemp, &c.; all of which are so important in the arts.

It may be obtained by taking any kind of wood, and treating it successively with water, acids, and alkalies. Anything that is soluble in the wood is thus washed out from it, and what is left behind is cellulose or lignine.

Each atom of it contains 12 of carbon, 8 of oxygen, and 8 of hydrogen.

Cellulose has a remarkable affinity for alumina, and this property is taken great advantage of in dyeing woven fabrics.

When pure, cellulose is quite white; and the bleaching that is employed to decolorise paper and other substances made from it, is requisite in order to remove the resins and other vegetable secretions which in the processes made use of for obtaining it in the arts always remain attached to it.

Lignine can by the vital forces of plants be converted into gum, and ultimately into sugar, although it is very doubtful if this is done upon any extensive scale. It is not certain either, whether the actions that go on in the stomachs of animals can also effect this change; but certainly the greater part by far of the lignine swallowed by animals is little affected by their digestive functions. Artificially by the action of hot sulphuric acid it passes into gum, and from that principle into sugar.

Exposed to dry air, or to water free from air, lignine undergoes no change; but if both air and water have access to it, oxygen is absorbed, water and carbonic acid are given off, and a series of compounds result that form the great bulk of fertile soil, as will be more fully described in Chap. VI. of this Book, under the head of "Humus and its Compounds."

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III. GUM AND ITS VARIETIES.

The sap of many plants contain gum, and it also frequently exudes from stems and branches. Many
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slight varieties of it exist in nature; but they are all characterised by being insoluble in alcohol, soluble in (either hot or cold) water, and by giving viscid and sticky solutions that may be employed to fasten two pieces of paper, &c. together. Gum is in no way acted upon by iodine, and never crystallises.

By contact with sulphuric acid gum is converted into dextrine (and subsequently into sugar), but not very readily.

An atom of gum contains 12 of carbon, 11 of oxygen, and 11 of hydrogen.

Two distinct kinds of gum are recognised by chemists.

a. Arabin, of which gum-arabic is a good example, and which is distinguished by dissolving in cold water.

b. Cerasin, which exists in the cherry tree, and which does not dissolve in cold, but does in hot, water.

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IV. MUCILAGE.

This is perhaps a variety of gum. When gum tragacanth, flax-seed and other vegetable productions are put into water, that fluid does not dissolve them, although the whole mass enlarges in bulk and forms a transparent jelly. The mucilage of the orchis-root used to be sold in the shops and streets under the name of salep.

By the action of sulphuric acid it is converted into dextrine.
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In chemical composition it is probably the same as gum.

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V. Sugar and its Varieties.

The different varieties of sugar exist abundantly in many plants, being in all cases probably derived from the starch. One variety of it exists in the milk of mammalia, this being the solitary saccharine proximate principle formed by an animal in a healthy state. There is, however, an abnormal condition, called diabetes, in which another variety of sugar is produced by the vital powers of animals.

All the sugars are distinguished from other subtances by being capable of undergoing at once the alcoholic fermentation.

a. Cane-sugar. This variety derives its name from being obtained on a large scale from the sugar-cane. It is also manufactured for commercial purposes from the maple and beet-root, and it exists abundantly in many other vegetables. The juice is evaporated and separates into a mass of brownish crystalline (sugar is an exception to the general law of organic substances not crystallising) grains called muscovado or raw sugar, and a brown liquid called molasses or treacle. Raw sugar contains a quantity of colouring matter and other ingredients derived from the juice, and these are got rid of by the action of albumen. The product of all this is loaf or refined sugar; and a strong solution or syrup of this, if laid aside in a warm place, is crystallised in oblique rhombs, and is commonly called sugar-candy.

Pure cane-sugar is white, odourless, and very sweet. Its specific gravity is 1·6. If struck or rubbed in the dark, it is phosphorescent. Heated up to 350° it fuses, and congeals, on cooling, into a hard, brittle mass called barley-sugar. If the temperature be raised to 630°, oxygen and hydrogen are given off, and a new dark-brown solution (caramel) is formed. If the heat be increased still more, it is altogether decomposed.

Sugar dissolves in one-third part of its weight of cold, and in all proportions with hot, water. A strong solution of sugar kept near the boiling point for some time becomes converted into uncrystallisable sugar, and this is a source of loss to the refiner and manufacturer. Sugar scarcely dissolves at all in alcohol, and but sparingly in weak spirits.

An atom of sugar consists of 12 atoms of carbon, 10 of hydrogen, and 10 of oxygen, with 1 atom of water.

When cane-sugar is acted upon by weak sulphuric (and many other vegetable acids) acid, aided by gentle heat, it is converted into grape-sugar; and both in nature and art this change is always brought about when cane-sugar is fermented.

b. Grape-sugar. This is even more abundant than the latter. It is the kind found in grapes and most fruits, and in honey. The sugar in these vegetables, however (honey of course is of vegetable origin), as originally formed by the vital powers from the starch of the sap, is probably cane-sugar, which is converted into grape-sugar by the action of tartaric or other vegetable acids.

As just mentioned, too, this variety of sugar may be obtained if to cane-sugar (or to starch or gum) weak sulphuric acid be added. The most convenient mode of doing this is to boil one part of starch in four of water and $\frac{1}{50}$ of sulphuric acid for 40 hours, carefully keeping up the quantity of water that is evaporated. At the end of this time the starch is completely converted into sugar; and if the acid be removed by means of lime, it may be obtained in a crystalline state from the solution. As the quantity of sugar formed in the vine varies according to the season, so the quantity of alcohol in the wine made from the vine varies. In many parts of France, however, now, if the must be deficient in sugar, sugar is manufactured in this manner from starch, and added to it.

Starch brought into contact with another substance, diastase (see p. 108.), becomes rapidly converted into dextrine, and thence into sugar. This process is very common in nature, and is imitated in art by the maltster and distiller.

Lignine may also be converted into grape-sugar by the action of sulphuric acid and water.

In its physical properties grape-sugar resembles cane-sugar, but it is much less soluble, and not so sweet.

An atom of it contains 12 atoms of carbon, 11 of oxygen and 11 of hydrogen, with 3 atoms of water.

Lignine, starch, gum, and cane-sugar, contain the same quantity of carbon; and their conversion into grape-sugar evidently depends upon their acquiring water, or the elements of water, under the influence of heat, sulphuric acid, and other acids. Thus, lignine $12C + 8H + 8O$ requires, in order that it may become converted into sugar, $4H + 4O$. Accordingly, when we convert lignine into sugar we would expect to have a heavier weight of sugar than we employ of lignine, the additional weight being obtained from the element of the water acquired by the lignine. Such is found to be the case, and 100 of sawdust acted upon by water under the influence of the acid yield 115 of sugar. By referring to the constitution of starch it will be seen that this proximate principle requires less hydrogen and oxygen to become converted into sugar. Accordingly, when starch is so converted into sugar, the gain in weight is half as much as in the case of lignine, 100 parts of starch yielding commonly 106 of sugar.

c. Lactine or Milk-sugar. If the whey of milk be evaporated, semitransparent, hard, gritty crystals of a faintly sweet taste are deposited. These are crystals of milk-sugar.

These crystals consist of carbon 24, hydrogen 19, and oxygen 19, with 5 of water. These last may, however, be driven off by means of heat.

By the action of sulphuric acid this sugar can also be converted into grape sugar.

It is used by the Swiss, and the Tatars employ it to form an intoxicating liquor.

By decomposition lactine yields a product which, although very different from most of the preceding, requires notice. It is—

Lactic Acid.

If sour milk, *i. e.* milk in which the lactine has been decomposed, is treated with carbonate of oxide of lead, a salt (the lactate of oxide of lead) is obtained in solution. If to this sulphate of oxide of zinc be added, sulphate of oxide of lead is precipitated; and from the solution that remains lactate of oxide of zinc is obtained by evaporation; and this may be decomposed by means of barytes. When this is done, lactic acid is obtained.

From the unclarified juice of cabbage, carrot, or beet-root a similar product is obtained. Carbonic acid and ammonia are given off, and the whole series of processes that take place is complex. Each atom of it contains 6 of carbon, 5 of oxygen, and 5 of hydrogen; that is, every atom of cane-sugar contains the elements of two atoms of lactic acid, so that an atom of sugar can be transformed into two of lactic acid, and this transformation is probably promoted by the contiguity of albuminous proximate principles. In accordance with this last-mentioned view, during the digestion of sugar in the stomach, lactic acid is abundantly formed.

There are one or two other proximate principles, as mannite, glycyrrhizine, &c., which closely resemble the sugars, but they are not susceptible of the alcoholic fermentation.

CHAP. IV.

THE OLEAGINOUS ORGANIC PRINCIPLES.

ALL animals and plants contain oleaginous proximate principles formed by the union of the three elements carbon, oxygen, and hydrogen; but in which the two latter elements are not in the same proportion as they are in water. In animals, fat is deposited in the cavities of the cellular tissue, and in the substance of muscles, glands, &c.; and in plants mainly in the cellular texture and around the seeds. When vegetable fats do not exist in sufficient quantities as to be separated by pressure, they may easily be obtained by digesting the plant in ether. The ether dissolves the fats, and by distilling this solution they are left behind.

All these oleaginous organic principles consist of a solid and a liquid portion, and their degree of solidity depends upon which of these preponderates. And in almost all of them the principal fatty substances that thus occur mixed are,—

Elaine - which is liquid.
Margarine } which are solid.
Stearine -

1. ELAINE.

Two subvarieties of this exist.

a Elaine. When olive and many other oils are exposed to cold, a portion freezes. The fluid that is left behind is elaine. This variety does not undergo any change in its composition when exposed to the air.

b Elaine. When walnut and other oils are similarly treated, this variety of elaine is obtained, which, when exposed to the air, absorbs oxygen rapidly, evolves carbonic acid, and changes into a resinous substance; and, if spread thin upon a piece of wood or the like, into a varnish. Oils that possess this property are called drying oils, and are used as such by painters.

An atom of elaine contains 94 of carbon, 87 of hydrogen, and 15 of oxygen.

2. MARGARINE.

The solid part of almost all vegetable oils, and of man, the goose, and other animals, is a white, hard, brittle substance that melts at 118°. It is called margarine.

An atom of margarine contains 74 of carbon, 74 of hydrogen, and 12 of oxygen.

3. STEARINE.

The solid part of a few vegetable oils and that of a great many animals, as that of horses, cattle, sheep, and pigs, is named stearine. It is also a hard, colourless, and brittle fat. It melts at 129°.

An atom of it contains 142 of carbon, 141 of hydrogen, and 17 of oxygen.

The mixed fats found in vegetables and animals, and composed of various mixtures of the above, are often accompanied by a minute quantity of some other fat peculiar to the animal and plant, and to which the odour, &c., are owing. And all the oils or fats formed by elaine, &c., are decomposed by heat, and cannot be distilled without decomposition, and are hence termed *fixed.*

It is now known, however, that elaine, margarine, and stearine are not ultimate proximate principles, but compound bodies of the nature of salts, and composed of an acid and the oxide of a base.

For instance, as is well known, when any of these fixed oils is boiled along with potassa or soda, a new compound called soap is formed, and a peculiar substance called glycerine, or, more correctly, oxide of glyceryle, is separated.

In the same manner, if we boil any of these fixed oils with oxide of lead, this oxide of glyceryle is separated, and the compound diachylon plaster is formed.

If, again, we take a solution of soap, and decompose it by adding sulphuric acid to it, sulphate of potassa or soda, as the case may be, is formed, and the substance that was in combination with the oxide of glyceryle is obtained. The same result is procured by decomposing diachylon by means of sulphuretted hydrogen.

If the soap have been made with elaine, the substance that is thus procured is elaic acid: if with margarine, margaric acid; and if with stearine, stearic acid.

So that soap is an eleate, stearate, or margarate of soda; diachylon, a ditto of oxide of lead; and elaine is the eleate of oxide of glyceryle; stearine, the stearate of the same substance; and margarine the margarate.

a. Elaic Acid. This acid, when cooled below 20°, congeals as a mass of needle-like crystals. At 60° its specific gravity is nearly 0·9. It is without taste or odour; it is insoluble in water, but abundantly so in alcohol; and this solution of it exhibits very decided acid properties.

Its composition is 44 of carbon, 39 of hydrogen, 4 of oxygen, and 1 of water.

b. Margaric Acid. This acid is solid up to 140°. It is white and crystallises in needles; is without taste or odour; may be volatilised without change; is soluble in hot alcohol, and this solution has decidedly acid properties.

Its composition is 34 of carbon, 33 of hydrogen, 3 of oxygen, and 1 of water.

c. Stearic Acid. This does not melt under 158°, and the melted acid forms a crystalline mass on cooling. As obtained by decomposing the stearate of potassa it occurs in brilliant white plates. It is volatile, insoluble in water, but soluble in alcohol.

Its composition is 68 of carbon, 66 of hydrogen, 5 of oxygen, and 2 of water.

d. Glycerine. This is a fluid. It is soluble in water and alcohol. It is an hydrated oxide of glyceryle.

Its composition is 8 of carbon, 7 of hydrogen, 5 of oxygen, and 1 of water.

From all these substances other compounds are formed by the actions of heat, nitric and sulphuric acids.

There are a few oleaginous proximate principles formed in some animals and plants which are not margarates, &c., of glycerine. Some of these require a notice.

(1.) *Cocoa-fat or Oil.* The kernel of the cocoa-nut contains a peculiar oil that is now extensively used in the manufacture of candles. It consists of a mixture of elaine and stearine, the latter being of quite a peculiar nature.

This cocoa-stearine is white and crystalline, and forms soaps with the alkalies; but when these soaps are decomposed by sulphuric acid instead of stearic acid a brilliant white substance is obtained. This fuses at 95°, and cannot be distilled without being decomposed. Its composition is stated at 27 of carbon, 26 of hydrogen, 3 of oxygen, and 1 of water.

(2.) *Palm-tree Fat or Oil.* This is now much used in the manufacture of soap. It is obtained by expression and by boiling from the fruits of the *Cocos butyracea* and another plant. It is about as solid as butter, has a yellow-red appearance, and an aromatic odour.

It contains common elaine, and also a modification of stearine, to which the name of palmatine has been given. This palmatine melts at 118°. It is insoluble in water, and nearly so in alcohol, but dissolves in ether. It forms with potassa a soap from which a peculiar acid—the palmatic—may be obtained. This acid is composed of 64 atoms of carbon, 62 of hydrogen, 6 of oxygen, with 2 of water.

(3.) *Castor-oil-tree Fat or Oil.* This is believed to consist of three peculiar acids, united with glycerine, which have been named ricino-stearic acid, ricinic and ricinic-elaic acid.

(4.) *Whale-oil or Fat.* Whale-oil and dolphin-oil, besides ordinary margarine, stearine, and elaine, contain a peculiar fat—delphinine—from which delphinic acid may be obtained. The composition of this latter is 10 atoms of carbon, 9 of hydrogen, and 3 of oxygen, with 1 of water.

(5.) *Spermaceti.* This is found in the head of the *Physeter macrocephalus* and some other whales. It is a very crystalline oil, which melts at 120°. By boiling with strong alkaline solutions it forms soaps; and when these are decomposed, elaic, margaric, and stearic acids are obtained; but the substance with which they have been combined is not glycerine, but a peculiar substance called ethale.

This ethale is a solid, crystalline, white substance, without smell or odour. It melts at 119°. Each atom of it contains 32 of carbon, 34 of hydrogen, and 2 of oxygen.

(6.) *Butter.* Ordinary butter contains stearine, margarine, and elaine. But it contains, in addition, three peculiar principles, which are compounds of glycerine with butyric, capric, and caproic acids. Of these acids the butyric is a clear, oily fluid, having the odour and taste of rancid butter, which indeed it communicates to this article of food; the caproic has a distinct odour, like that of human perspiration; and the capric crystallises. These acids have been little examined.

(7.) *Wax.* Beeswax is a mixture of two substances, cerine and myracine; the former of which is soluble in alcohol, the latter not. In the wax of some flowers two or three other peculiar principles have been found, all composed of carbon, oxygen, and hydrogen, and more will probably be discovered.

The volatile oils, as they are called, do not belong to the oleaginous proximate principles, and are noticed along with the resins in another section of this Book.

CHAP. V.

THE ALBUMINOUS ORGANIC PRINCIPLES.

THE albuminous proximate principles occur abundantly in animal and vegetable structures, and are of great interest and importance. They all contain carbon, oxygen, and hydrogen; a considerable proportion, usually fifteen or more per cent., of nitrogen; and, but in minute quantities, sulphur, phosphorus, lime, magnesia, and the other inorganic constituents of plants and animals elsewhere referred to. In the analyses of them that have been made these last have been generally neglected, and our information regarding them is limited.

The albuminous proximate principles of plants are formed by the vital powers out of probably the starch, the ammonia, the nitric acid, and the inorganic constituents of the sap; all of which have been, of course, derived from without. The albuminous proximate principles of animals are derived from the vegetable ones taken into the stomach.

1. ALBUMEN.

A great part of the structure of animals consists of albumen. It exists in two forms. In one, as it occurs in the blood, the egg, or the humours of the eye, it is soluble, and dissolves in water; and in the other, as in almost all the solid tissues, it is insoluble. The white of egg is the most convenient source of animal albumen. It is distinguished by coagulating on being heated up to 160°, or by the addition of an acid (the acetic excepted).

Almost all plants, and nearly all parts of plants, contain vegetable albumen. It, too, exists in two forms, being soluble in the sap and insoluble in the husks and envelopes of many seeds, &c. The best manner of obtaining vegetable albumen is to filter the expressed juice of a plant, and then to apply heat up to 160°, or to add an acid. In either case the coagulated albumen is thrown down in all respects analogous to the boiled white of an egg.

The insoluble vegetable albumen may be obtained from husks, &c., by boiling them in acetic acid.

2. FIBRINE.

This animal principle is, in the living blood, soluble; but it coagulates immediately the blood is taken from the body, or the animal dies. It occurs in the muscles as a soft, elastic solid, arranged in fibres; from which circumstance it receives its name.

It is most conveniently obtained by whipping fresh-drawn blood with twigs of birch. As it coagulates it adheres to the twigs. It is insoluble in water; but, like albumen, dissolves in acetic acid. It differs mainly from that principle, in coagulating spontaneously and without heat, and by catalytically decomposing the binoxide of hydrogen.

Gluten. This is the name given to vegetable fibrine. When wheaten flour, or analogous vegetable substances, is washed in a linen cloth, the starch is passed away, and a tenacious paste remains behind, which is often called gluten. It is, however, a mixture of vegetable albumen and gluten; but the two are readily separated by boiling in alcohol, by which the gluten is dissolved and the albumen left behind. When water is added to this alcoholic solution, the gluten is precipitated. It is when moist an elastic, tenacious mass, and when dried resembles horn.

3. Caseine.

Animal caseine occurs in milk. In this fluid it exists dissolved in a solution of carbonate of soda. If any acid is added, it combines with the alkali, and the caseine is precipitated. This caseine differs from fibrine in not coagulating spontaneously, and from albumen in not coagulating by heat and in being coagulable by acetic acid.

Vegetable caseine occurs in many plants, and is most conveniently obtained from leguminous seeds. By mixing the powder of these with water the starch falls to the bottom, and albumen may be separated by means of heat. If an acid be then added to the remaining liquor, the caseine is thrown down.

Emulsine, legumine, and avenine, are probably varieties of caseine.

The above substances are probably identical in their chemical constitution, as far as regards the proportion of carbon, oxygen, hydrogen, and nitrogen that they contain, and their difference depends upon the amount of inorganic constituents—sulphur, phosphorus, lime, soda, magnesia, &c.—which they have associated with them. The following may be put down as their proportional composition: —

Carbon - - -	54·96
Hydrogen - - -	7·15
Nitrogen - - - -	15·80
Oxygen - - - -	21·73
Inorganic constituents -	0·36
	100·

Albumen, it will be observed, is coagulable by heat, and by the acids, with the exception of the acetic; fibrine coagulates spontaneously; while caseine coagulates by the addition to its solution of any acid, including the acetic; but does not coagulate spontaneously, nor by the application of heat.

Considering the great similarity between these substances, Mulder was led to infer that they were compounds of a peculiar principle which he called proteine, with varying quantities of sulphur and phosphorus. And he found that when any of them were dissolved in potassa by the aid of heat, and acetic acid added, a grey-white substance fell down. This proteine has distinct chemical characters, but is at least in this country usually regarded as a product of decomposition. Farther notice of it may, therefore, be dispensed with. In the same manner kreatine and other supposed organic proximate principles may be omitted.

Three other organic compounds, however, belonging to this group demand attention. These are—

1. Gelatine.

When the skin, cellular or serous tissues, tendons, and bones of animals are boiled in water, a portion of them is dissolved out, which, as the water cools, forms a jelly. This is gelatine; and a very familiar, although impure, variety of it is glue. When pure, gelatine is quite colourless and transparent, little soluble in cold water, but readily so in hot; and this hot solution forms on cooling so firm a jelly, that with $\frac{1}{100}$ part of it it becomes a consistent solid, and is hence used to fasten pieces of wood, &c., together. It does not dissolve in ether or alcohol. Its proportional constitution is as follows:—

Carbon	47
Hydrogen	7
Nitrogen	16
Oxygen and inorganic constituents	27
	97

The most important chemical property of gelatine is its tendency to combine with tannic acid and form a compound that is insoluble in water, and commonly known by the name of leather. The reaction between these two bodies is so strong, that one part of gelatine in one thousand parts of water is at once detected by an infusion of galls.

2. Diastase.

This compound is produced by the decomposition of albuminous proximate compounds; and is very remarkable, on account of the catalytic action that it possesses.

It is produced by the action of air and water upon the gluten of the seed when it is germinating. It may be obtained, although not in a state of purity, from germinated barley, or malt as it is called. To do this the malt should be bruised and mixed with a little water, and the liquor expressed; and to the residue alcohol then added, which precipitates a quantity of albumen. On evaporating, diastase, in the form of a white gummy mass, is obtained. One part of it rapidly converts a solution of 2000 parts of starch in water, first into dextrine, and then into grape-sugar. It has also the power of converting a solution of sugar at a certain temperature into alcohol. The nature of this last change is described in p. 94.

3. Hematosine.

This is the colouring material of the globules of the blood. It is obtained by a somewhat difficult process, and is a dark-brown mass, which, when heated, evolves ammoniacal products, and is insoluble in water, alcohol, and ether. It contains a quantity of iron. It otherwise consists of 44 of carbon, 22 of hydrogen, 3 of nitrogen, and 6 of oxygen.

CHAP. VI.

HUMUS AND ITS COMPOUNDS.

When the dead body of a plant is exposed to air and moisture, its chemical relations undergo a change. Its vitality being lost, its chemical elements can no longer remain united together so as to form lignine. But still they are not at once restored to the dominion of inorganic chemistry, and converted into carbonic acid, &c.; but any albuminous matter that may be present acts as a ferment *, a catalytic action ensues, and a dark-brown substance, that which darkens soil, is formed, to which the name of humus is given.

This humus, however, is a complex substance, and a great many varieties and modifications of it exist; and this arrangement affords, as we shall very soon have occasion to see, an instance of very elaborate design. When wood decomposes, a substance called ulmic acid, containing an excess of hydrogen, is produced. This, by obtaining from the air oxygen, becomes converted into humic acid; this humic acid obtains more oxygen, and becomes geic, and this geic passes into crenic and apocrenic acids. These last are

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* Accordingly, if a substance, as bichloride of mercury, which forms an insoluble compound with albumen, be added to wood, decomposition does not take place.

mainly in the end converted into carbonic acid. Each of these acids demands a short notice.

1. ULMIC ACID.

If most soils or peats be boiled in a solution of carbonate of soda, ulmate of soda is formed; and, on adding hydrochloric acid, the ulmic acid is thrown down in the form of a brown powder. It is very sparingly soluble in water, and forms combinations with alkaline and earthy bases. Ulmic acid consists of carbon and water, with an excess of hydrogen. Some obtained (Mulder) from Frisian turf had the following composition:—

Carbon	40
Water	16
Hydrogen	2

2. HUMIC ACID.

When most soil, particularly soil of a darker colour than that which yields only ulmic acid, be similarly treated with carbonate of soda and hydrochloric acid, a black, and, when dry, shining powder, falls down, which is humic acid. This also is little soluble in water; combines with alkalies and earths: but in chemical constitution it consists only of carbon and water; *i. e.*, the hydrogen of the ulmic acid has combined with oxygen, and formed the humic acid under notice. The chemical constitution of some taken from the soil of a pasture field was as follows:—

Carbon	40		Oxygen	14	Hydrogen	14
or Water	14	*i.e.*	Oxygen	14	Hydrogen	14

3. GEIC ACID.

Several other organic acids exist in soil. The composition of some has been ascertained, and is as follows:—

1. Geic acid and carbon	40	Water	15	Oxygen	2
2. Crenic acid	24	„	12	„	4
3. Apocrenic acid	48	„	12	„	12

Their character is, that they contain carbon, water, and an excess of oxygen. Of these acids the geic is not very soluble, but the crenic and apocrenic dissolve in water. All three are always found in the soil combined with ammonia; and the apocrenic has probably a tendency to go on appropriating oxygen until it eventually becomes carbonic acid.

These acids will again fall under our notice in Chap. XXI. of this Book "On Soil," and in Chap. III. of the following one on "The Food of Plants." We may here recapitulate that the first change that the vegetable matter undergoes is its conversion into an acid consisting of

Carbon—Water—Hydrogen,

and the compounds of which are insoluble in water: that this acquires oxygen, and passes into an acid consisting of

Carbon—Water:

the superfluous hydrogen of the former being now oxidated and forming the additional water, the compounds of this acid being also insoluble; that more oxygen is then obtained, the resulting acid being composed of

Carbon—Water—Oxygen;

and the compounds of this acid are to some extent soluble: that more oxygen being obtained, the result is

Carbonic acid—Water.

If the dead vegetable were at once converted into carbonic acid, the soil would not have a constant supply of this gas; and were the compounds first formed soluble, they would be washed away, and no carbonic acid formed in the upper soil.

CHAP. VII.

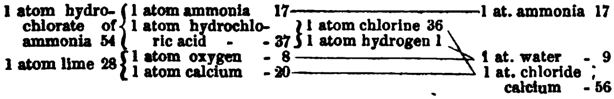
AMMONIA AND ITS COMPOUNDS.

As the result of the first decomposition of the saccharine proximate principles of plants is humus, so when the albuminous proximate principles of animals lose their vitality, they are resolved into a compound of very great interest and importance—ammonia.

Each atom of ammonia consists of one atom of nitrogen and three of hydrogen, and it is the only compound of these substances that we can procure in an isolated form; although we infer, as will immediately be mentioned, that they do unite in another proportion. Ammonia is the volatile alkali of the older writers.

This volatile alkali had clearly a very limited existence in the early days of the world before plants and animals had been called into being. It is almost invariably the product, in one way or another, of the putrefaction of compounds containing nitrogen that have ceased to be vitalised. Thus it is formed when any of these are exposed to air and moisture and allowed to rot, and also much more rapidly when such are distilled at high temperatures; the latter being the manner indeed in which ammonia is for commercial purposes generally prepared. Also, when any recently-living nitrogenised substance is putrefying there is a catalytic action set up; and the hydrogen that is evolved abstracts nitrogen from the atmosphere, and ammonia is the result. It may likewise be synthetically formed by mixing the two constituents of it and passing electricity through them, and is, perhaps, abundantly formed in this manner and brought down to the soil during a thunder-storm attended by rain.

For examination in the laboratory ammonia is always obtained from sal-ammoniac, or hydrochlorate of ammonia, by the action of quicklime. The decomposition that takes place is as follows:—



Owing to its being very readily absorbed by water it should be collected over mercury.

Ammonia is a colourless and invisible gas, having a strong and peculiar odour. Its specific gravity is ·59. By a pressure of six and a half atmospheres it may, at a temperature of 50°, be converted into a fluid. It is slightly combustible, but does not support combustion; and when mixed with air or oxygen forms a very explosive mixture. It reddens turmeric paper, but the red colour disappears on the application of heat; and it forms dense white fumes with hydrochloric acid. It likewise communicates a deep-blue colour to salts of copper. By these three properties it may be always recognised.

Ammonia, as mentioned above, is very readily absorbed by water, which, at a temperature of 32°, takes up 780 times its volume. During the absorption great heat is evolved, and the solution, or water of ammonia, augments two-thirds in volume and boils at 120°. This water possesses all the chemical properties of the gas.

The volatile alkali is so called, because in its chemical relations it exactly resembles the oxides of the alkaline metals. Like them it reddens turmeric, and like them it neutralises the strongest acids, and indeed as a base ranks next to lime. Its real nature, however, is not decided. It may be a basyle composed of one atom of nitrogen and three of hydrogen, or it may be a compound of a radical composed of two atoms of hydrogen and one of nitrogen, which it has been proposed to call ammidogene, which has formed a union with an atom of hydrogen. It is not necessary here to enter into the reasons of this supposition, which is pretty generally received. If such is the case, the correct name of ammonia is ammidide of hydrogen.

It is common, however, to consider, that there is a substance composed of ammonia, plus an atom of hydrogen, and of a metallic nature; and as this enables one to more easily consider the salts of ammonia, it is best to mention it. Upon this hypothesis the salts of ammonia exactly resemble the corresponding compounds of potassium and sodium. Thus we may describe the same compounds of ammonia, or of this ammonium, as follows:—

Hydrochlorate of ammonia - $(N+3H)+(Cl\,H)$.
or,
Chloride of ammonium - - $(N+4H)+Cl$.

Or, in like manner,

Hydrosulphate of ammonia - $(N+3H)+(H+S)$.
or,
Sulphuret of ammonium - - $(N+4H)+S$.

Or, in like manner,

Sulphate of ammonia - - $(N+3H)+(HO)+(S+3O)$.
or,
Sulphate of oxide of ammonium $(N+4H)+O+(S\ 33O)$.

In support of the existence of a substance like ammonium, which resembles the metals, it may be stated, that if mercury and sodium are heated together they form an amalgam; and if to this amalgam a saturated solution of sal ammoniac be added, the masss wells up, retaining its metallic lustre. The compound, however, is transitory, but it may be of the nature of an amalgam of mercury and ammonium.

The atomic weight of ammonia is 17, and its symbol $N+3H$.

The compounds of this substance with the non-metallic elements described in this Chapter are as follows: —

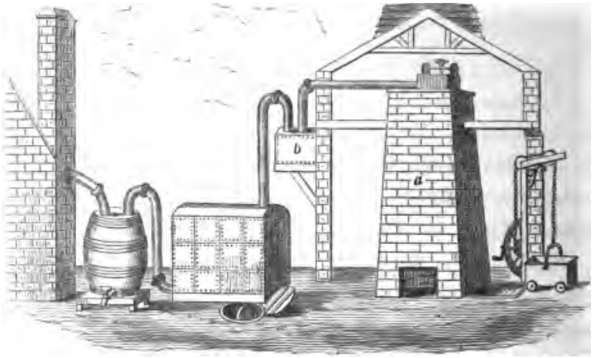
	Base.	=	Acid.	Formula.
1. *Hydrochlorate of ammonia* -	1 atom 17	+	1 atom 36=53	$(N+3H)+(H+Cl)$.
2. *Hydrosulphate of ammonia* -	1 atom 17	+	1 atom 17=34	$(N+3H+(H+S)$.

1. HYDROCHLORATE OF AMMONIA, OR CHLORIDE OF AMMONIUM.

This is the sal ammoniac of old writers, and the muriate of ammonia of still more recent, but now obsolete, nomenclatures. It is prepared extensively in commerce by the destructive distillation of bones.

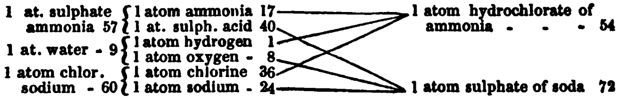
These are boiled, to remove the fat (which is employed by the soap-makers), and then distilled. *Fig.* 109.

Fig. 109.



represents an establishment for the purpose. The retort *a* is of bricks, and is placed perpendicularly in the furnace. The bones are introduced at the top, and the fire placed around it. The volatile parts are conveyed along the tube into the cistern *b*, and from thence into the iron receiver. Here a brown liquor called bone-spirit, and which contains carbonate of ammonia and also an empyreumatic oil, are deposited. The non-condensable portion is a fetid and inflammable gas, which passes on through the cask to the chimney, where it is burned. What is left in the retort is used for animal charcoal.

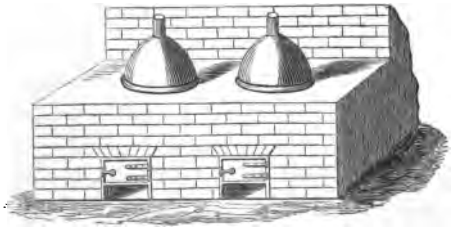
During the process, water, carbonic acid, and ammonia are formed, and the mixture in the receiver is an impure solution of carbonate of ammonia. To this sulphuric acid is added, the result being the formation of sulphate of ammonia, while the carbonic acid is driven off into the air. To this sulphate chloride of sodium is added, upon which the following decomposition ensues:—



Of course the sulphate of ammonia in this process is obtained in a solid form by evaporating the solution of it, and the solid sulphate and the chloride are sublimed together.

This salt is also procured from the refuse of the gas-manufacturer; and as this refuse is often wasted even in localities where large sums are paid for artificial manure, it is proper to notice the process. During the distillation of coal the nitrogenous matter becomes converted into ammonia, which unites with carbonic and other acids. Sulphuric acid is added, and these salts are decomposed, the resulting sulphate of ammonia being obtained in brown crystals by evaporation. This sulphate is mixed with common salt, and heated in an iron lined with clay, such as represented in *fig.* 110. The resulting hydrochlorate

Fig. 110.



is sublimed, by means of heat, into the head of the apparatus.

Sal ammoniac has a pungent, saline taste; is soluble in both water and alcohol; crystallises in feathery crystals, and sometimes in cubes and octohedrons; and sublimes, unchanged, at a temperature below ignition.

It is employed in the arts in the tinning of iron and other metals, and in the preparation of tin mordants for dying scarlet.

2. Hydrosulphate of Ammonia.

This is formed by mixing together sulphuretted hydrogen and ammonia gas. A bihydrosulphuret may be obtained by passing sulphuretted hydrogen through water of ammonia. This is of great importance in the laboratory for the detection of metals as it forms metallic sulphurets.

The compounds that ammonia forms with the oxacids are most conveniently described as salts of oxide of ammonia.

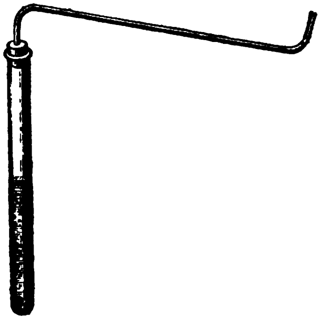
CHAP. VIII.

CYANOGEN AND ITS COMPOUNDS.

Cyanogen is one of the substances that was not originally created, but is the product of decomposition. It is also the best example that we have of a compound salt radical; and, although composed of one atom of nitrogen and two of carbon, it forms combinations like an elementary body, and in its affinities very much resembles chlorine.

The easiest mode of procuring it is to take some cyanide of silver (a compound of cyanogen and silver) put in the bottom of a tube, *fig.* 111., the top of which is closed by a cork, from which pro-

Fig. 111.



ceeds a small gas tube. On applying gentle heat decomposition takes place, and the cyanogen is evolved, and may be collected over mercury.

Cyanogen is a colourless gas that has a very peculiar odour, resembling that of peach-blossom. It is soluble in alcohol and water. It is inflammable, and burns with a pale, rose-coloured flame, the result of the combustion being carbonic acid and nitrogen. It is heavy, having a specific gravity of 1819. If some cyanide of mercury be placed in a strong tube, bent as in *fig.* 28., p. 129., Vol. I., and then closed and heated at *a*, the cyanogen is condensed by a pressure of about four atmospheres and condenses as a fluid at *b*.

The atomic weight of cyanogen is 26, and its symbol (2C+N or) Cy.

The compounds of cyanogen described in this section are as follows: —

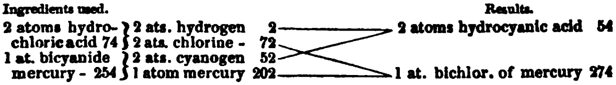
					Formula.
1.	*Cyanide of hydrogen*	Cyanogen 1 atom	+Hydrogen 1 atom	= 27	Cy+H.
2.	*Cyanic acid*	Cyanogen 1 atom	+Oxygen - 1 atom	= 34	Cy+O.
3.	*Fulminic acid*	Cyanogen 2 atoms	+Oxygen - 2 atoms	= 68	2Cy+2O.
4.	*Cyanuric acid*	Cyanogen 3 atoms	+Oxygen - 3 atoms	=102	3Cy+3O.
5.	*Ferrocyanogen*	Cyanogen 3 atoms	+Iron - 1 atom	=106	3Cy+F.
6.	*Ferridcyanogen*	Twice as much as the preceding.			
7.	*Sulphocyanogen*	Cyanogen 1 atom	+Sulphur - 3 atoms	= 74	1Cy+3S.

1. CYANIDE OF HYDROGEN, HYDROCYANIC OR PRUSSIC ACID.

This is the most powerful of all known poisons. Some idea of its strength and energy may be inferred from the facts that the prussic acid of the shops is so diluted as only to contain three per cent. of real acid, and that yet a drop is a dose, and that an overdose can produce death in ten seconds.

Prussic acid is a constituent in the water distilled from the leaves and blossoms of several fruits; but it does not naturally exist in such, being formed in the distillation, and is also obtained by the destructive distillation of many substances that contain nitrogen.

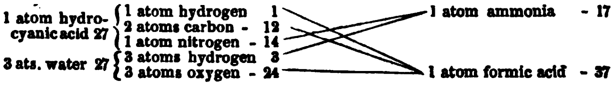
Several processes, all complicated, are used in pharmacy for procuring diluted prussic acid. To obtain the strong acid, the best plan is to add strong liquid hydrocyanic acid to bicyanide of mercury; to pass the vapour that results over carbonate of lime in order to free it from hydrochloric acid, and then over chloride of calcium to get rid of water. The receiver should be immersed in a freezing mixture. What remains in the retort is corrosive sublimate. The nature of the decomposition is thus indicated: —


Ingredients used.
Results.
2 atoms hydrochloric acid 74
2 ats. hydrogen 2
2 ats. chlorine - 72
1 at. bicyanide mercury - 254
2 ats. cyanogen 52
1 atom mercury 202
2 atoms hydrocyanic acid 54
1 at. bichlor. of mercury 274

This anhydrous hydrocyanic acid is a colourless liquid, which boils at 80° and congeals at 5°. It is very volatile; and if a drop be put upon a glass rod, a portion evaporates and produces so much cold as to freeze the remainder. Its odour is suffocating and pungent, and its taste bitter and acrid. Owing to its virulence as a poison, it is a very dangerous substance to have anything to do with.

Exposed to light this acid undergoes a spontaneous decomposition, ammonia being formed, and also a substance of which the nature is not yet ascertained.

In contact with water and strong acids, the water and prussic acid are decomposed, and ammonia and prussic acid produced as follows: —



The best test for the presence of prussic acid is nitrate of silver, which throws down a white precipitate of cyanide of silver, which may be distinguished from the white chloride of that metal by being soluble in boiling nitric acid. By adding potassa, salts of iron, and sulphuric acid, prussian blue may be obtained, as will be understood when that substance has been investigated.

2. Cyanic Acid.

To obtain this substance, ferrocyanide of potassium of commerce (which is a cyanide of iron and cyanide of potassium) is heated and stirred; upon which the cyanide of potassium absorbs oxygen, and becomes converted into cyanate of potassa. If this be pounded and digested in boiling alcohol, as the alcohol cools it is deposited in crystals. If sulphuric acid be poured upon these, the cyanic acid is liberated. The greater portion of it is immediately decomposed, but some of it may be obtained. It is a colourless liquid, and has a very peculiar odour, somewhat like that of acetic acid.

If this acid be mixed with ammonia, it forms a substance exactly analogous to urea.

3. FULMINIC ACID.

This acid is of importance in consequence of the detonating property of its salts. It has never yet been obtained in an isolated form.

To prepare fulminate of oxide of mercury, mercury is dissolved in nitric acid, and the nitrate of oxide of mercury thus obtained is poured into rectified spirits of wine. The changes that take place are intricate and almost inexplicable; the alcohol and the free nitric acid produce water, acetic acid, and fulminic acid; which latter attaches itself to the oxide of mercury; and this fulminate may be obtained by washing with boiling water.

Fulminate of oxide of mercury detonates violently when struck between two hard bodies, and is the substance employed in percussion-caps.

4. CYANURIC ACID.

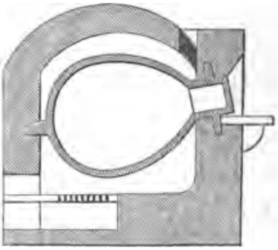
This compound is of little importance. It is prepared by heating the cyanate of ammonia until the ammonia is driven off. Three atoms of the cyanate of ammonia, it will be noticed, contain the elements of three atoms of ammonia and one of cyanuric acid.

5. FERROCYANOGEN.

This is the name given to a supposed salt radical which consists of three atoms of cyanogen and one of iron. It is only by assuming this base that we can understand the composition of the—

Ferrocyanide of potassium, or yellow prussiate of potassa, a substance much used in the arts. An atom of this compound consists of ferrocyanogen and potassium, with some water. To prepare it, some animal substance containing nitrogen (and dried blood is found the best of these), pearl-ashes, and iron filings are mixed together, and put into an egg-shaped earthen furnace, such as represented in *fig.* 112.,

Fig. 112.



and exposed to heat for from eight to twelve hours. The carbon and nitrogen of the animal matter unite together to form bicarburet of nitrogen or cyanogen; this unites with the iron, forming ferrocyanogen; and, this acts as a salt radical, and attaches itself to the iron.

The easiest mode of accounting for the changes that take place in this decomposition, would be to say, that when the cyanogen is formed it unites with the iron and with the potassium, and that the product is a double cyanide of iron and potassium. But this compound, or prussiate of potassa, does not act with the tests of iron as it would do, were this the case; and hence the necessity of assuming the existence of ferrocyanogen.

Ferrocyanide of potassium crystallises in octohedrons of a beautiful light-lemon colour, which, when heat is applied, become white. If the heat is increased, and air have access, it absorbs oxygen, and becomes cyanate of potassa; but if the process be conducted in close vessels, some of the nitrogen is expelled, and cyanide of potassium and carburet of iron are left behind. Digested with oxide of mercury, cyanide of mercury is formed, and iron and potassa set free.

Prussiate of potassa is much used for testing metallic solutions. With solutions of silver, mercury, bismuth, tin, lead, nickel, zinc, and manganese it gives a white precipitate which turns red, a chocolate colour with that of copper, &c. But its most important action in this respect is with solutions of iron. Added to a solution of persulphate of iron, the beautiful pigment prussian blue, which is a mixture of protocyanide and sesquicyanide of iron, is precipitated. If a solution of protosulphate be similarly treated, a white precipitate is the result, which, however, gradually, on being exposed to the air, becomes blue.

6. FERRIDCYANOGEN.

This is another supposed radical, each atom of which is believed to consist of the elements of two atoms of ferrocyanogen.

When chlorine is passed through a solution of ferrocyanide of potassium until the liquid cease to precipitate, a per-salt of iron (a reddish green solution) is obtained, which yields ruby-red crystals. These are crystals of the ferridcyanide of potassium, or the red prussiate of potassa. This substance, when added to a per-salt of iron, merely colours the solution green; but with a solution of a proto-salt it gives a blue precipitate even richer in colour than prussian blue proper, and which is known in commerce under the name of Tennant's prussian blue. It differs from the other prussian blue in containing the same quantity of protocyanide with half as much sesquicyanide.

7. Sulphocyanogen.

Sulphocyanogen is another radical of a similar nature. Salts of it produce with a per-salt of iron a blood-red precipitate. Other analogous radicals are mellon, platino-cyanogen, &c., the theoretical constitution of which is obscure.

CHAP. IX.

THE ATMOSPHERE.

The atmosphere is usually described as a part of inorganic chemistry, and said to be composed of oxygen and nitrogen. But its relations to organic nature are very important, and it always contains, in addition to these two elements, ammonia, carbonic acid, and watery vapour. It is therefore described in this division.

The atmosphere may be regarded as an aëriform ocean which extends around this planet, having a depth (or a height) of about forty-five miles. It possesses, of course, several important physical properties; but here we have only to consider its chemical ones. Every hundred measures of air contain about

79 measures of nitrogen.
21 ,, of oxygen.
$\frac{1}{13}$ to $\frac{1}{30}$,, of carbonic acid.
A small quantity of ammonia.
A varying quantity of watery vapour.

As far as regards animal beings, the action of the nitrogen appears to be simply mechanical; and the purpose that it serves is to dilute the oxygen with which it is simply mixed, and not chemically united. But it has other actions in respect to plants and inorganic matter. When an electric spark is transmitted through a mixture of oxygen and nitrogen, a very small portion of the two elements unite, and form nitric acid. Accordingly during a thunder storm a little nitric acid is generated in the atmosphere, and washed down into the soil as a nitrate by the rain. As we shall hereafter see, soluble nitrates probably afford food to plants, and it is to this cause perhaps that the increased growth that may be witnessed after a thunder storm is to be ascribed. In this manner the nitrogen of the atmosphere, although to a very small extent, is a source of nourishment to vegetables.

Then, with regard to inorganic matter, the nitrogen of the atmosphere forms some important chemical compounds. Thus, when noticing nitre beds, we saw that when potassa was present along with decomposing animal matter, a catalytic action was set up, and that the nitrogen of the air, combining with oxygen and potassa, formed saltpetre. In the same manner, although it is never done in making prussiate of potassa, the azote may be obtained from the atmosphere; and it is not absolutely necessary that the organic matter used contain any of it.

The oxygen of the atmosphere plays a most important part, and, with regard to animals, the most important part. No animal can remain alive unless its blood receive very frequent supplies of oxygen, which are always obtained from the atmosphere. In like manner, as we have often had occasion to see, almost all inorganic matter, and also much of the matter that has been vitalised and is on its way to an inorganic state, are continually abstracting oxygen from the air and forming new compounds which have usually influential properties and destinies. Combustion, too, requires the presence of oxygen, which this process largely abstracts from the atmosphere.

Considering the vast number of animal beings, the constant oxidation of inorganic matter that is going on, and the great number of fires, it might at first be apprehended that the quantity of oxygen would be rapidly lessened; but, as we shall hereafter see, as much oxygen is constantly being ejected into the atmosphere by plants as practically to keep up the proportion and compensate for the consumption. As, however, man goes on increasing in number, and forests disappearing, it is evident that there must be a (although a very slight) diminution of oxygen.

The carbonic acid is as necessary for the support of plants as oxygen is for the continuance of animal life. Their leaves absorb it from the atmosphere, and their vital forces decompose it, appropriate its carbon, which is added to their structure, and then restore the oxygen to the air. The air is kept fully supplied with carbonic acid by the respiration of animals and combustion. At an early period in the world's history it is believed that the quantity of carbonic acid contained in the atmosphere was much greater than it is at present; and that all the carbon now contained in animal and vegetable structures existed in the atmosphere combined with oxygen. Indeed, it is possible, that at first the atmosphere contained no free oxygen, but that it was a mixture of nitrogen and a very large quantity of carbonic acid.

The ammonia of the atmosphere is entirely or nearly derived from exhalations from the putrefaction of animals and plants. Hence the original atmosphere of the earth possessed no ammonia, and the quantity of it is gradually, although slowly, increasing. Indeed, were it not washed upon the soil every time that it rains or that dew falls, and consumed by plants, as will be seen when considering the food of plants, the quantity of ammonia in the air would soon become very great.

The quantity of aqueous vapour which has risen from evaporation from the sea, &c., into the air, varies in different places according to the temperature and other causes. Masses of this condensed vapour constitute clouds, and when two clouds of different temperatures approach, a quantity of water or rain is precipitated, which brings ammonia down with it, and then trickles through the earth; from a spring flows into a river, in that way reaches the ocean; from whence it rises by evaporation, and once again forms part of a cloud.

Although the change has been and is very slow, it is evident that the composition of the atmosphere has from the beginning been gradually altering, and that it is yet altering. At first composed of nitrogen and carbonic acid, the primeval plants decomposed the acid, and set free the oxygen. When successive generations of animals rotted, ammonia was poured into the air, and, notwithstanding its appropriation by plants, it is probably annually increasing. As man increases, and forests disappear, the oxygen becomes less; and we can imagine that a time may come when from this cause human existence shall be impossible. But, before such a result could be produced, it is probable that the quantity of ammonia in the air would become so great that an explosive mixture would be formed, and everything destroyed by fire.

CHAP. X.

WATER.

THE water of the laboratory is the oxide of hydrogen, and is prepared from natural water by the process of distillation. Water, however, as it occurs in nature, is a more complex substance; and, as it has important relations to organic life, is most appropriately noticed here.

Water, besides the protoxide of hydrogen, always contains carbonic acid and air, and usually, also, some organic matter (commonly ammonia), and a number of salts, of which chloride of sodium, sulphate and carbonate of lime, and chloride of magnesium, are the most important.

Water exists in great abundance, the quantity of it far exceeding that of the atmosphere. It is absolutely essential to all organised structures, and none can exist without it. With some it forms hydrates; but most structures have it mechanically mixed among their atoms, and seem to require to have it so mixed in order that they may be kept alive. It moistens them, and also serves to hold some of their solid constituents in solution. Then the moisture of water is necessary to enable the organs of animals and plants to grow and be fed. Not only must the food be mixed with water, but, after it has been assimilated to the nature of any particular animal or plant, this food must be conveyed to every part of it along with a large quantity of water, in the form of blood or sap. Then there is no doubt but that it is in plants decomposed upon a large scale, and its elements appropriated.

The constituents, too, of actual water, are very useful. This fluid penetrates almost every portion of the soil, and presents to the plant both ammonia, apocrenic acid, and the inorganic constituents, as they are called, which are necessary for vegetation.

The specific gravity of water is unity, and is about 815 times that of air. The vapour of water, however, some of which is always present in the atmosphere, is lighter than that gaseous admixture, and therefore tends to ascend in it.

Sea-water differs from rain-water and most spring water in abounding in saline ingredients. Some mineral waters, however, contain so large a quantity of saline matters and gases which they have obtained from the rocks through which they flow, that their taste, smell, and action upon the animal economy are quite altered and different from those of ordinary water. An attempt has been made by Dr. Gairdner to generalise the connection between the peculiarities of these mineral waters, as they are called, and the geological formations in which they occur. He states that those found in primitive formations are nearly all thermal, and that some of them are very hot; and that they contain sulphuretted hydrogen, free carbonic acid, silica, and, in general, salts with a soda base, and a little lime or iron. In the older secondary formations the mineral springs are still found thermal, but not so hot as in the preceding; the sulphuretted hydrogen is wanting, and free carbonic acid is rare; soda salts still predominate, but silica is not common, and sulphate of lime is a common ingredient. In the mineral springs of the newer secondary and tertiary formations are found carbonate and sulphate of lime, sulphate of magnesia and oxide of iron; but there is no free carbonic acid, and they are cold. In trap and volcanic formations the sulphuretted hydrogen, the free carbonic acid, and the silica reappear, and the sulphate of lime, the magnesia, and the iron are again wanting. They contain carbonate of soda, and often free sulphuric and hydrochloric acids. Some of the springs arising from secondary formations contain iodine.

CHAP. XI.

THE FERMENTATIONS AND THEIR PRODUCTS.

WHEN the saccharine juice of any plant, as grape-juice or apple-juice, which besides the solution of sugar contains some albuminous proximate principle, be exposed to a temperature of about 80°, the albuminous proximate principle begins to putrefy, and communicates a catalytic action to the sugar; the result of which is, that the sugar parts with carbonic acid, and becomes converted into alcohol. The previous sweet taste is gone, and the new compound possesses peculiar actions upon the nervous system.

If we take pure sugar and dissolve it in water, and expose it to a temperature of 80°, no change takes place. But if we add to it some albuminous principle in a state of decay, or some putrefying gluten, putrid meat, or yeast (which is albuminous matter derived from malt), the change begins to take place; carbonic acid is discharged and alcohol formed.

That an atom of grape-sugar should yield two atoms of alcohol, and four of carbonic acid, is plain, on consideration of their formulas. Thus: —

$$\begin{array}{ll} \text{An atom of grape sugar contains} \ - & 12C+12H+12O. \\ \hline \text{Two atoms of alcohol contain} \ \cdot \ - & \left\{\begin{array}{l} 4C+\ 6H+\ 2O. \\ 4C+\ 6H+\ 2O. \end{array}\right. \\ \text{Four atoms of carbonic acid contain} & \left\{\begin{array}{l} C \quad\quad +\ 2O. \\ C \quad\quad +\ 2O. \\ C \quad\quad +\ 2O. \\ C \quad\quad +\ 2O. \end{array}\right. \\ \hline & 12C+12H+12O. \end{array}$$

Of course these saccharine juices contain water and other substances, which, after the fermentation, remain mixed with the alcohol. The name given to this mixture of alcohol, water, &c., when obtained from grape-juice, is wine; from apple-juice, cider; from honey, mead; and from an infusion of malt, beer or ale. The fermented infusions of a mixture of malt and raw grain, the starch of the latter being converted into sugar, are called by the distillers washes. From all of these a mixture of alcohol, water, and oil can be obtained by distillation. The oil and a portion of the water are removed by repeated distillation, and by admixture with carbonate of potassa, which has a powerful affinity for water. The mixture of alcohol and water that still remains is termed, in general, ardent spirit; and when obtained from wine or cider, is usually called brandy; when from sugar, rum; and from corn, whisky. For purposes of luxury, some of these are flavoured, and constitute liqueurs, the most familiar example of which is gin. A kind of whisky, without any flavouring, used in the arts, is called spirits of wine.

When any of these have a specific gravity of ·920, they contain 49 per cent. of alcohol, and are said to be proof spirit. The rectified spirit of the shops has a specific gravity of ·839, and contains about 83 per cent. of alcohol.

For scientific purposes it is desirable to obtain from rectified spirit pure or absolute alcohol. This is done by distilling it with chloride of calcium, which entirely abstracts its water. Absolute alcohol is a limpid, colourless, and very combustible liquid. Its specific gravity at 59° is ·794. It boils at 173°, and no cold has ever been known of sufficient intensity to freeze it.

If equal weights of alcohol and sulphuric acid are mixed together, a new product is formed, which may be obtained in a separate state by neutralising the acid with carbonate of potassa, and distilling. It is named ether. It consists of the same elements as alcohol, but has an atom less of hydrogen and oxygen. We may, instead of putting down the composition of alcohol as $4C+6H+2O$, state it thus $(4C+5H+O)+(1\ Aq, \text{ or } HO)$. When the acid is added to this it abstracts this atom of water, and ether is the result.*

If, as stated in Chap. II. of this Book, an excess of acid be employed, the elements of two atoms of water are abstracted from each atom of alcohol, and olefiant gas is the result.

Ether is a limpid, transparent liquid, having a very peculiar odour and taste. Breathed continuously, it induces complete insensibility, and, before the employment of chloroform, was used as an anæsthetic. Its density is 735. It boils at 97°, and at common temperatures evaporates, producing much cold in so doing. It is very combustible, dissolves a great many substances, and in particular oils and fats. It combines with the acids, and forms compounds called nitric ether, acetic ether, &c.

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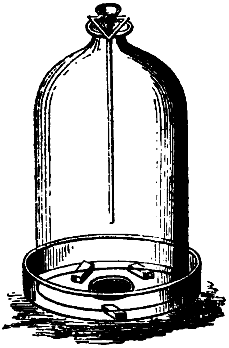
* This account of the decomposition is not exactly correct, but is given on account of its simplicity. The sulphuric acid abstracts the water, and then forms sulphate of oxide of ethyle. This unites with more acid, and a bisulphate or sulphovinic acid is produced. By heat this is resolved into ether, water, and hydrated sulphuric acid.

It is believed that ether is the oxide of a hypothetical salt basyle that acts as a metal, and on which the name of ethyle has been bestowed. Viewing the matter in this light, the following table will illustrate the composition of this class of substances:—

Ethyle	$4C+5H$.
Ether, or oxide of ethyle	$(4C+5H)+O$.
Alcohol, or hydrate of oxide of ethyle	$(4C+5H)+O+HO$.
Chloric ether, or chloride of ethyle	$(4C+5H)+Cl$.
Nitric ether, or nitrate of oxide of ethyle	$(4C+5H+O)+(N+5O.)$

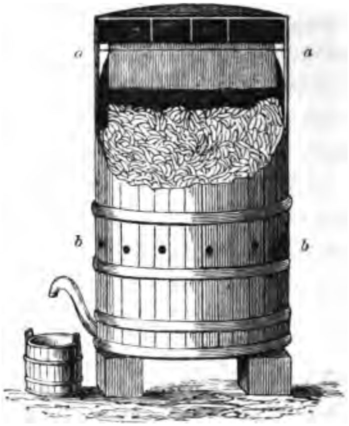
By oxidating alcohol we obtain vinegar or acetic acid. This may be done by the action of platinum in a very fine state of division, or platinum black. To effect this, a large bell-glass, as in *fig.* 113., open at the top, is taken and supported upon a basin in such a manner that the air has ready access to its interior. A funnel passes through its top just over a watch-glass, in which some black platinum is placed; strong alcohol is dropped through the funnel, and falls upon the platinum, where it (the alcohol) is instantly converted into vinegar. In this case the platinum merely presents to the alcohol a quantity of air, which of course contains oxygen, and this oxygen unites with the alcohol and produces this new compound.

Fig. 113.



In the same manner, if any weak solution of alcohol, as weak beer, weak wine, or cider, be exposed to the atmosphere along with a little ferment, a catalytic action takes place, the alcohol becomes oxidated, and acetic acid is produced. The change is still farther expedited if the alcohol is much subdivided, and by consequence a larger surface of it brought into contact with the air. This is done by filling a cask, as in *fig.* 114., with wood-shavings. This is closed at the top by a pan *a*, the bottom of which is perforated by a number of small holes, through which short threads are placed. Before putting in the shavings they are soaked in old vinegar, which is found to have itself a catalytic action upon diluted alcohol. Below, at *b b*, is a circle of holes, about half an inch in diameter, and which freely admit the air. The alcohol and water, or weak beer, or whatever may be the form of the diluted alcohol that is employed, is poured in at the

Fig. 114.



top, and trickles slowly down by means of the threads, and is diffused over the shavings, forming a thin liquid layer which presents a very extended surface to the oxygen of the air. So much of this oxygen unites with the alcohol, and so rapidly, as to resemble combustion, and the temperature of the liquid rises to 104°, and in the course of about thirty-six hours all the alcohol has acquired as much oxygen as is sufficient to convert it into acetic acid.

Another mode of obtaining acetic acid, by distilling wood, will be noticed in the next Chapter.

Acetic acid has never yet been obtained in an anhydrous state. Each atom of it is always associated with at least one atom of water. This protohydrate is at a temperature below 60° a crystalline solid; between that and its boiling point, which is 248°, it is a colourless liquid of an agreeable and peculiar smell. Applied to the skin, it blisters it. Acetic acid forms salts called acetates, some of the most important of which will soon be brought under our notice; and when it combines with metallic oxides, the bases take the place of the water; and acetate of soda, for example, consists of anhydrous soda and anhydrous acetic acid. If we considered hydrogen as a metal, and water as its protoxide, we should say that, when we mixed protohydrate of acetic acid with the soda, the former was decomposed, and the oxide of hydrogen precipitated.

Acetic acid is held to contain a peculiar radical named acetyle, and the following table represents the chief compounds that it is believed to form :—

Acetyle - - - -	$4C+3H$.	
Oxide of acetyle - - -	$(4C+3H)\,O$. -	This also is a hypothetical substance.
Hydrate of do. or aldehyle -	$(4C+3H)\,O+HO$.	The process for procuring it is omitted.
Acetous acid - - -	$(4C+3H)\,2O+HO$.	do.
Acetic acid - - - -	$(4C+3H)\,3O+HO$.	do.

If diluted alcohol is distilled along with chloride of lime, a most wonderful anæsthetic agent, and one that has quite superseded ether, is obtained. Each atom of it consists of two atoms of carbon, three of chlorine, and one of water. It is a heavy, colourless liquid, having an agreeable odour and a pleasant taste. A very small quantity of it, when inhaled, produces complete insensibility, which is not generally attended by unpleasant after-consequences. If it is mixed with a solution of potassa, it is decomposed; chloride of potassium and a substance commonly called formic acid, and composed of two atoms of carbon, one of hydrogen, and three of oxygen, part of the latter having been derived from the potassa, are obtained. It is called formic acid, because it exists in the ant (*formica*), and is the cause of the pain of its sting. It may be obtained by distilling the bodies of ants along with a little water, and also artificially. It is believed to be the oxide of a peculiar basyle called formyle. In this case the following table will indicate the composition of it, of formic acid, and of chloroform:—

Formyle - - - -	$2C+H$.
Formic acid, or teroxide -	$(2C+H)+3O$.
Chloroform, or terchloride -	$(2C+H)+3Cl$.

The acetates noticed in this Chapter are

1. *Acetate of soda.*
2. *Acetate of alumina.*
3. *Acetates of oxide of lead.*

All these are known by the acetic odour which they emit when sulphuric acid is added to them, and by the white, pearly precipitate that they produce when the nitrate of silver is put into their solutions.

1. Acetate of Soda.

This may be easily prepared by saturating carbonate of soda with acetic acid. It is a white neutral salt, occurring in oblique rhombic crystals which have a cool bitter taste. Each atom of it contains one of acid, one of base, and six of water. On the large scale it is prepared by saturating pyroligneous acid with chalk, and decomposing the acetate of lime thus obtained with sulphate of soda. This commercial acid is used in pharmacy as the source of acetic acid.

2. ACETATE OF ALUMINA.

This is used as a mordaunt in dying. That employed by the dyer is made by mixing alum and acetate of lead, and contains a considerable admixture of acetate of potassa.

3. ACETATE OF LEAD.

This salt, commonly called sugar of lead, is prepared on a large scale by dissolving oxide of lead in acetic (pyroligneous) acid. It occurs in crystals, the primary form of which is a right rhombic prism. Their taste is astringent and sweet. Each atom of it contains one of acid, one of base, and six of water.

By boiling together acetate of lead, oxide of lead, and water, a tribasic acetate is obtained, the solution of which is known in pharmacy as Saturnine extract, or Goulard water.

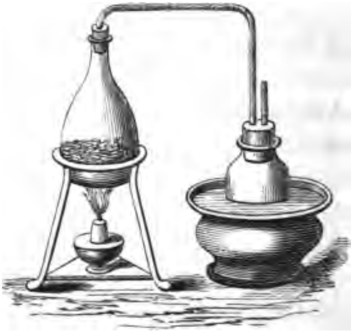
CHAP. XII.

THE DISTILLATION OF WOOD AND COAL.

Wood, when heated with a free access of air, is converted into carbon and water, its inorganic constituents being left behind as ash. But when the access of air is imperfect, other compounds are formed, as is indicated by the peculiar smell of the smoke and the appearance of the soot. These compounds do not pre-exist, and are best examined when the air is altogether excluded and the wood distilled.

This may be managed on the small scale by using apparatus such as drawn in *fig.* 115. On applying heat to the flask containing the wood, the charcoal

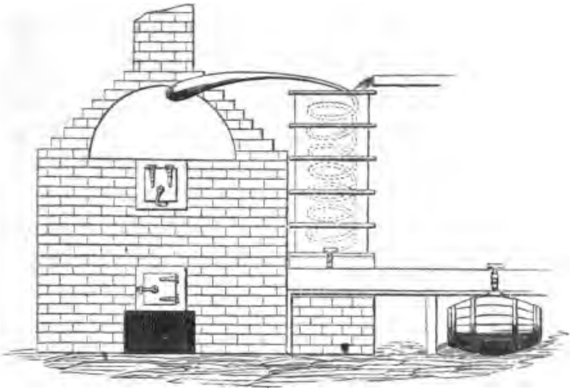
Fig. 115.



remains behind, the carbonic acid, oxide, carbonic and carburetted hydrogen escape, and in the receiver will be found a watery acid and a thick, brown, resinous liquid. These are pyroligneous acid and wood-tar.

Pyroligneous acid is now manufactured on a large scale, and is a very abundant source of commercial acetic acid. *Fig.* 116. represents a manufactory of it.

Fig. 116.



The wood employed is preferably oak, ash, or birch. After specimens of these have been put into the still, and the furnace lighted, a quantity of charcoal is left in the still, various gases, which are not condensable, are allowed to escape, and the mixture of acetic acid, creosote, and tar, are condensed in the receiver. The greater part of the tar falls to the bottom, and the upper layer consists of wood vinegar, which is essentially acetic acid holding in solution some tar and creosote. A pound of dried beech wood is found to yield about half its weight of crude acid. It has a brownish-black colour, a smoky odour, and a very peculiar flavour. The acetic acid is obtained from it by saturating it with lime, and decomposing the acetate of lime thus procured by sulphate of soda. The acetate of soda is then distilled with sulphuric acid, the result being sulphate of soda and acetic acid.

Pyroligneous acid possesses very powerful antiseptic properties, which are owing to its containing a peculiar substance named creosote, each pound of the acid containing about two drachms of it.

The process for obtaining creosote is so tedious and troublesome, that it may be omitted. It is a colourless and transparent oily fluid, having the smell of smoked meat. It coagulates albumen, and is a powerful antiseptic. Indeed, the Egyptian mummies are said to be entirely preserved by it. Its composition is not very accurately known, but it is believed to consist of 14 atoms of carbon, 9 of hydrogen, and 2 of oxygen.

When pyroligneous acid is slowly distilled, a volatile liquid, very like alcohol, is obtained. This is called pyroxylic spirit, or hydrated oxide of methyl, a hypothetical compound base*, which it is not necessary to notice here.

If this pyroxylic spirit be brought into contact with platinum black (in the same manner as alcohol, as described at p. 140.), hydrogen is removed, and oxygen is absorbed, the result being the formation of hydrated formic acid.

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* Each atom of which contains 2 atoms of carbon and 3 of hydrogen. Each atom of the spirit contains $(2C+3H)+O+HO$.

The wood tar contains a large quantity of carbon. By distillation it may be separated into a volatile oil and a non-volatile black pitch, which is probably the oil oxidated.

Coal is the fossil wood of extinct forests, and only differs from existing wood in having been subjected to immense pressure, and in apparently having given off some of its water and some carbonic acid. The destructive distillation of coal produces, therefore, nearly the same results as that of wood. The gaseous products are carburetted hydrogen, &c.; charcoal, or coke, as it is in this case called, is left behind; an empyreumatic liquor is obtained, which, however, contains little pyroligneous acid, but which has a considerable quantity of ammonia*, derived from the albuminous principles of the extinct forests, and a quantity of tar, which may be separated into a volatile substance and a pitchy, non-volatile one. This last contains several peculiar substances, of which the one most examined is naphthaline, a compound that forms an immense number of combinations. The substance sold as naphtha, and which seems analogous to petroleum, formed in the bowels of the earth probably by the action of heat upon coal, is believed to be a hydrated oxide of a radical to which the name of phenyle has been applied.

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* There is always too, some sulphuretted hydrogen the sulphur of which is derived from the sulphur of the coal.

CHAP. XIII.

THE RESINS AND ESSENTIAL OILS.

We have in this and the three succeeding chapters to consider compounds, some of which, like alcohol, are artificially formed from vegetable structures, but some others of which are naturally elaborated in the structure of plants. But even in this latter case they are of no use to the plant in which they are formed. They are (or at least many of them) of the greatest service to man, and the provisions made for their secretion and formation were clearly part of a plan the leading feature of which is, that this material world is made for the purpose of being subordinate to the wants of the human species. The bodies noticed in this chapter may be arranged into—1. Volatile Oils, 2. Camphors, and 3. Resins.

1. Volatile Oils.

All these oils are volatile at ordinary temperatures. They contain carbon, hydrogen, and generally, but not always, oxygen, and sometimes sulphur; but the element that predominates in them is hydrogen. They dissolve only in liquids that are rich in hydrogen and poor in oxygen, as in alcohol for instance, but not, except in a small degree, in water. They often absorb oxygen, and, when they have done this, become either resins or acids. They may be arranged into two classes—1. Essential oils, forming acids, and not pre-existing in the plant; and 2. Those existing in the plant, and not forming acids. As samples of the first of these we may take the oil of bitter almonds and the oil of mustard.

Oil of Bitter Almonds. All the plants that yield prussic acid also yield this oil; but as it is procured most abundantly from the bitter almond, it is called by that name. Both the acid and the oil are obtained from the decomposition of a substance called amygdaline, which may be thus obtained:—Bitter almonds are powdered and strongly pressed between warm iron plates, in order to remove the fixed oil, and the residue is boiled in very strong alcohol. This alcohol dissolves the amygdaline along with some sugar, and, if the sugar be removed, the amygdaline falls down as a white powder. Of course the easiest way of getting rid of the sugar is by adding a little yeast, upon which fermentation ensues, and it is converted into alcohol. The amygdaline is purified by solutions and crystallisations, in alcohol. When pure, it forms silky needles that are tasteless and inodorous. Its formula is $40C + 27H + 22O + N$.

Pure amygdaline may be boiled in water without being altered; but when bruised bitter almonds are distilled with water, a number of compounds, including the oil in question and prussic acid, are obtained. The fact is, that the cotyledon of the almond, besides amygdaline, contains an albuminous substance which has been called emulsine, which, however, in the unbruised fruit is contained in distinct cells from the amygdaline. When the bruised almonds are mixed with water, this emulsine induces a catalytic action, the results being probably as follows:—

One atom of amygdaline is decomposed into - - - - - (*i.e.* $40C+27H+22O+1N$.)	1 atom hydrocyanic acid	$2C+\ H+N$.	
	2 atoms almond oil -	$28C+12H$	$+\ 4O$.
	½ atom sugar - -	$6C+\ 5H$	$+\ 5O$.
	2 atoms formic acid -	$4C+\ 2H$	$+\ 6O$.
	7 atoms water - -	$7H$	$+\ 7O$.
	Total - -	$40C+27H+1N+22O$	

The oil of bitter almonds is obtained by distilling bruised bitter almonds with water. As thus procured, it contains prussic acid and other admixtures, from which it is freed by distillation with water, chloride of lime, and iron. It is then a colourless oil, having a peculiar odour. It is now believed to be a hydruret of a hypothetical radical called benzyle, the formula of which is $14C+5H+3O$, and the proposed symbol of which is Bz. The formula of oil of bitter almonds is therefore $Bz+H$.

A great many compounds of this benzyle have been described by the chemists; but the only one necessary to be noticed here is its oxide, or benzoic acid. This occurs naturally in some plants, constituting the flowers of benjamin and dragon's-blood of the shops, and may be artificially formed by oxidating oil of bitter almonds or amygdaline. It also exists in the excretions of herbivorous animals. It forms with bases a number of salts termed benzoates.

Oil of Mustard. Mustard seeds contain a compound which may be obtained by a process similar to that employed for obtaining amygdaline. Mustard also contains an albuminous ferment, which, when the seeds are bruised and mixed with water, catalytically cause the sulphosinapisine (as it has been proposed to call it) to become converted into an oil which has the following composition, $32C+20H+4N+5S+5O$. A name of the albuminous ferment is myrosyne.

The volatile oils that pre-exist in different parts of plants are very numerous; a great many plants having their peculiar volatile oils, and some of them two or three different kinds. They all contain a liquid oleopten, and a stereopten; the latter of which is apt to become solid, and which is, in fact, camphor.

Some of these volatile oils, as those of lavender, mint, fennel, anise, &c., are composed of carbon, hydrogen, and oxygen; while others, as those of juniper, pepper, and turpentine, consist only of carbon and hydrogen. A great many of these latter are isomeric.

2. CAMPHORS.

These are, in fact, the stereoptens of the essential oils. Common camphor, which is obtained from the *Laurus camphora*, or camphor tree, may be taken as the type of them. It forms a white, semi-transparent mass, that crystallises in irregular octohedrons. It is tough and very difficult to powder, has a bitter taste, is soluble in alcohol, and sparingly so in water. Its taste and odour are peculiar. Its formula is $20C+16H+2O$.

Other camphors are obtained from attar of roses, oil of fennel, peppermint, turpentine, &c.

3. Resins.

A resin is an oxidised volatile oil; and when these resins have attained this degree of oxidation, they have little tendency to combine with more oxygen, and hence are smeared over wood, &c. to protect them from decay. The commonest of them is resin, or colophony, which is obtained from the oil of turpentine, and modifications of which are known by the name of pitch, cobblers' wax, &c. Among other oxidised oils or resins may be enumerated copal, mastic, lac, and amber.

When resins and volatile oils are mixed together, the compound is named a balsam; and when with the resin there is associated gum, we have a gum resin.

Two substances that are of the nature of resins, are caoutchouc and gutta percha. Both consist only of carbon and hydrogen.

CHAP. XIV.

THE ORGANIC ACIDS AND THEIR MOST IMPORTANT COMPOUNDS.

A NUMBER of compounds are formed in plants which in their chemical relations exactly resemble the inorganic acids, and form salts with bases. Those noticed in this Chapter are—

I. The Tartaric.
II. The Racemic.
III. The Citric.
IV. The Malic.
V. The Meconic.
VI. The Tannic.
VII. The Gallic.

I. THE TARTARIC.

This acid is formed in several vegetables, as the pepper-plant, tamarinds, the pine-apple, but most abundantly in the vine. When we express grape-juice, we find the tartaric acid combined with potassa, forming the bitartrate of potassa. When by fermentation the sugar of the grape-juice is converted into alcohol, this bitartrate remains unaffected; but as it is not very soluble in alcohol and water, it gradually falls to the bottom of the cask or bottle in which the wine is kept. This crust of wine, or bitartrate of potassa, is called in commerce argol, and is the source of the tartaric acid of the shops.

The great distinction between wine and other fermented drinks, as beer, cider, gooseberry wine, &c., is, that wine possesses this tartaric acid, while the others have it not, but the malic instead. Hence, in fermenting the juices of other fruits besides the grape, if a fermented drink resembling grape wine is desired, bitartrate of potassa must be added.

In order to obtain tartaric acid, the argol of commerce is taken and deprived of its colouring matter by the action of charcoal. It is then dissolved in water and mixed with chalk, the decomposition that takes place being as follows: —

Ingredients used.			Products.	
1 Chalk - 50	1 carbonic acid -	22	1 carbonic acid	22
	1 lime - - -	28		
1 Bitartrate of potassa 180	1 tartrate of potassa	114	1 tartrate of potassa	114
	1 tartaric acid -	66	1 tartrate of lime	94

By adding chloride of calcium to the solution of tartrates of potassa, more tartrate of lime is obtained. Both portions of tartrate of lime are then decomposed by sulphuric acid, the following changes taking place: —

Ingredients used.			Products.	
1 at. tartrate of lime 94	1 at. tartaric acid	66	1 at. tartaric acid	- 66
	1 at. lime -	- 28		
1 at. sulphuric acid 40	- - - -	- 40	1 at. sulphate of lime	- 68

Tartaric acid crystallises in sour, transparent, inodorous crystals, that belong to the oblique prismatic system. When heated it parts with its water of combination, and various acids are successively formed, the notice of which may be here omitted. Tartaric acid dissolves readily in water, but sparingly in alcohol. It is distinguished by giving with salts of potassium a white precipitate (bitartrate of potassa). It is, like pyrophosphoric acid, bibasic. Its symbol is $(4C+2H+5O)+(H+O)$, or, for shortness, $\bar{T}$.

The salts of tartaric acid that it will be here necessary to notice are:—

	Base.	Acid.
1. *Tartrate of potassa* - - - -	KO	$+\bar{T}$.
2. *Bitartrate of potassa* - - -	$2KO+HO$	$+\bar{T}$.
3. *Tartrate of potassa and soda* - -	$KO+NCl$	$+\bar{T}$.
4. *Tartrate of potassa and antimony* -	$KO+St.\,Cl$	$+\bar{T}$.

1. TARTRATE OF POTASSA.

This may be formed by adding cream of tartar to a hot solution of carbonate of potassa, until the latter is neutralised. The reaction that takes place is evident. If any acid be added to its solution, it takes half the potassa, and cream of tartar is precipitated.

2. BITARTRATE OF POTASSA.

As already mentioned, this is elaborated by the vine, and, not being very soluble in wine, is deposited at the bottom of casks containing that liquid. This deposit is known by the name of argol, or oxide of tartar. This is dissolved in boiling water, some kind of clay added to combine with the colouring matter, and, as the solution cools, the purified bitartrate falls down in right rhombic prisms. It is, as may be inferred from the above process, sparingly soluble in cold water. Heated alone, it is converted into a mixture of charcoal and carbonate of potassa, or black flux, and when deflagrated with nitre, the charcoal is oxidated, and carbonate of potassa (when thus obtained, called white flux) is obtained. The use of these fluxes is elsewhere noticed.

3. Tartrate of Potassa and Soda.

The popular name of this salt is Rochelle salts. It is obtained by adding carbonate of soda to a hot solution of bitartrate of potassa, upon which carbonic acid is disengaged, and the soda combines with the bitartrate. It occurs in large, transparent crystals, the primary form of which is the right rhombic prism, but, very curiously, they are frequently produced in halves. It dissolves in two parts of cold water, and readily in hot.

4. Tartrate of Potassa and Antimony.

This is commonly called tartar emetic. It is prepared by boiling together a solution of cream of tartar and sesquioxide of antimony. The oxide replaces the atom of water in the cream of tartar. By evaporation and cooling the tartar emetic is obtained in white, transparent, inodorous crystals, which are rhombic octohedrons. They have a slightly sweet taste, which becomes afterwards metallic, dissolves in fourteen parts of water at 60°, and in two at 212°. They are insoluble in alcohol.

II. THE RACEMIC.

This acid is only mentioned for the sake of curiosity. It has exactly the same composition as the tartaric, is formed by the vines that grow about the Vosges mountains, and only there in certain seasons. It closely resembles tartaric acid in all its chemical relations, but differs in requiring ten times as much water for its solution, in its corresponding salts not having the same crystalline form, in the racemate of potassa and soda not crystallising at all, but forming a gummy mass and in another particular. The two acids afford a very good example of isomerism.

* * *

III. THE CITRIC.

This acid is also produced in the vegetable kingdom. It usually occurs free, but sometimes combined with potassa or lime. In the fruits of the genus *citrus*, and in the cranberry, &c., it is found alone; mixed with malic acid, it is present in gooseberries, currants, strawberries, and cherries, and in the tamarind it is associated with both malic and tartaric acids. It is prepared from lemon juice by neutralising it with chalk, and thus obtaining an insoluble citrate of lime. This is decomposed by means of sulphuric acid, and the result is, that sulphate of lime and citric acid are obtained.

Citric acid occurs in right rhombic crystals. These have an agreeable sour taste, are soluble in their own weight of cold, and half as much hot water; and, when heated, successively converted into aconitic and a variety of other acids. Its formula may be stated as $(12C+5H+11O)+(3HO)+2\,Aq$. It is tribasic. Its salts, however, need not detain us.

* * *

IV. The Malic.

This acid occurs in the apple, the garden rhubarb, &c., but is purest and most abundant in the berries of the mountain-ash or rowan-tree. It is prepared from the last-mentioned by a somewhat complicated process, which may be here omitted. It is deliquescent, and very sour. When heated it is converted into fumaric and other acids. It is bibasic, but its salts are of no importance. Its formula is $(8C+4H+8O)+(2HO)$.

* * *

V. The Meconic.

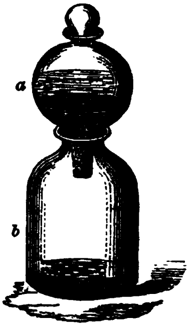
This acid is found in opium, and in that substance alone. To obtain it, an infusion of opium in cold water is made, to which chloride of calcium is added; the result being, that meconate of lime is thrown down. This is treated twice with hydrochloric acid, which combines with the lime, and the meconic acid is obtained in crystals. These, when pure, are in white scales, which are soluble in four parts of boiling water. Heated, meconic acid forms a succession of acids. It is tribasic. It strikes, with solution of peroxide of iron, a blood-red colour, which differs from that of sulphocyanide in giving a white precipitate with acetate of lead, which, when heated with sulphur and potassium, and dissolved in water, gives no red colour with the salts of iron. The formula of meconic acid may be stated as $(14C+H+11O)+3(HO)$. Each atom is also associated with two other atoms of water, which it gives off at a heat of 212°.

VI. THE TANNIC ACID, OR TANNIN.

This organic acid exists in the bark of a great many exogenous trees, particularly in that of the oak. It is also found in the roots of tormentilla, &c., in the leaves of roses, and most abundantly of all in the gall-nuts that grow as excrescences upon the oak.

It is most conveniently obtained from these last mentioned; and to do so the apparatus sketched in *fig.* 117. is employed. *a* is a glass funnel, which may be closed at the top, and rests in a bottle, *b*; the tube of the funnel is stopped up with a bit of cotton; some powdered galls are introduced into the funnel; and over these some ether of the shops, which contains about ten per cent. of water, is poured. In the course of three or four days there is found in the bottle two layers of fluid; the upper is ether, the lower a concentrated solution of tannic acid in water. The fact is, that the attraction of tannic acid for water is so great as to withdraw it from the ether and dissolve in it, to the exclusion of every other constituent of the gall-nut. The water is removed from the tannic acid by evaporation in *vacuo*, some sulphuric acid being present to absorb the water.

Fig. 117.



Tannic acid is a yellowish-white substance, of a crystalline texture; it has an extremely astringent taste. With gelatine it forms the insoluble compound called leather. Exposed to the air it acquires oxygen and becomes converted into gallic acid. It is tribasic. Its formula is $(18C+5H+9O)+3(HO)$.

Tannic acid gives variously coloured precipitates with metallic solutions, and is hence used as a test. The following table represents the colour of the precipitate thrown down by the infusion (or tinctures) of galls with the metallic salts.

With solutions of	
Zinc	None,
Cadmium	
Protoxide of iron	
Manganese and alkaline and earthy salts	
Lead	White,
Antimony	
Copper	Gray,
Tin	Yellow,
Nickel	
Cobalt	
Silver	
Bismuth	Orange,
Platinum	Green,
Chromium	Brown,
Gold	
Peroxide of iron	Black.*

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* This is ink.

VII. THE GALLIC.

This acid does not exist in nature, but is formed when tannic acid is exposed to oxygen, when one atom of it absorbs eight of oxygen. It does not form leather with gelatine; and although it strikes a black colour with persalts of iron, this colour soon spontaneously disappears. It is bibasic. When the tannic acid is decomposed by being exposed to the air, four atoms of carbonic acid are given off, and two atoms of gallic acid remain. Its formula is therefore $(7C+H+3O)+12(HO)$.

Tannic acid may also be formed catalytically, but the process is quite obscure.

When gallic acid is heated it is converted into pyrogallic acid, and if the heat be continued afterwards, into others.*

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* By boiling charcoal in nitric acid, or by mixing almost any vegetable substance with sulphuric acid, and applying heat, an artificial tannin may be obtained. The nature of the action that takes place, and indeed that of the substance itself, are not understood.

CHAP. XV.

ORGANIC ALKALIES.

THESE substances are formed in plants, and in their chemical properties very much resemble ammonia. Like it, each atom of them is composed of a union of elements; like it, they invariably contain nitrogen; and, like it, they act as bases, forming neutral salts with acids, and affect vegetable colours. Whether in them the nitrogen is part of a compound radical analogous to amidogene is not ascertained.

The organic alkalies noticed in this Chapter are—

I. **Morphia.**
II. **Quinia or quinine.**
III. **Strychnia.**
IV. **Coneia.**
V. **Nicotiana.**

* * *

I. MORPHIA.

This is the active principle of opium, in which it exists combined with meconic acid, forming the meconate of morphia. It is most easily obtained from the hydrochlorate by adding ammonia, which unites with the acid and sets it free.

Pure morphia occurs in transparent crystals, the primary form of which is the right-rhombic prism. It is nearly insoluble in cold water, but boiling water can take up about the hundredth part of its own weight of it. It is not very soluble either in alcohol, forty parts of cold alcohol only dissolving one of it. If morphia (or any of its salts) be added to a solution of sesquichloride of iron, the solution becomes of a deep blue colour; which is lost by adding an excess of acid, and restored by neutralising this with an alkali; and with tannic acid it gives a white precipitate. It also possesses the property of deoxidising iodic acid and liberating the iodine..

The formula of morphia is $N + 35C + 20H + 6O$.

HYDROCHLORATE OF MORPHIA.

This is prepared for medicinal use by decomposing an infusion of opium from which the feculent matter has been separated by means of either chloride of lead or chloride of calcium; upon which the meconate of morphia is decomposed, and meconate of lead (or calcium) and hydrochlorate of morphia are formed. This latter is then obtained by evaporation, decolorised by animal charcoal, and purified by recrystallisation.

II. QUINIA.

This alkaloid exists in Cinchona bark, combined partly with sulphuric acid, and partly with an organic acid, the kinic, which it has not been thought necessary to describe in the preceding Chapter. To procure quinine the easiest method is to decompose the sulphate of quinine (which is largely manufactured for medicinal purposes) by means of caustic potassa, or ammonia; the white curdy precipitate that falls down, on the addition of the alkali, being dissolved in a very small quantity of spirits of wine, and this being then gently evaporated.

Quinia is inodorous and extremely bitter. One part of it requires 400 of cold and 250 of hot water to dissolve it; it, however, dissolves in boiling alcohol. Its salts are generally crystallisable, and are soluble in both water and alcohol. Its formula is $N+20C+12H+2O$.

SULPHATE OF QUINIA.

This is largely prepared for therapeutical purposes. The process followed essentially consists in decomposing the kinate of quinia by means of an alkali or alkaline earth. It is a basic salt, containing two atoms of base to one of acid. It is not very soluble in water; but by the addition of a little sulphuric acid it is converted into the neutral sulphate, which is soluble in ten parts of cold water.

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III. STRYCHNIA.

This organic alkali occurs along with another one, brucina, in several species of *strychnos;* and it is also
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a constituent in the famous wourali poison, used by the Indians for poisoning their arrow-heads. It exists in the plants in combination with an organic acid, to which the name of strychnic has been given. This strychnate of strychnia is decomposed by means of lime, and the precipitated strychnia dissolved out by means of alcohol, and purified by repeated crystallisations. In the shops it is almost always mixed up with more or less of brucine; an adulteration which may be detected by nitric acid, a substance that strikes a red colour with brucine but not with strychnia.

Pure strychnia occurs in octohedral crystals, which are white and intensely bitter. It is almost insoluble in water, and only slightly so in absolute alcohol; but is in spirits of wine. It forms salts with the acids. It is extremely poisonous. Its formula is $2N+44C+22H+4O$. It differs, it will be observed, from the other alkalies in containing two atoms of nitrogen.

* * *

IV. CONEIA.

This exists in the hemlock in combination with coneic acid. This salt is decomposed by potassa. It is a liquid, and also remarkable for having the smallest atomic weight of any known organic alkali, its formula being $N+12C+14H+O$, altogether not 109. The atomic weight of the preceding, or strychnia, is 348, and that of morphia 292.

V. NICOTIANA.

This is the alkali of tobacco, and may be prepared in a similiar manner to coneia. Like that substance, it is liquid. Its formula is not yet established.

CHAP. XVI.

ORGANIC COLOURING MATTERS.

CERTAIN proximate principles exist in organic structures, which are neither acids nor bases, and which do not belong to the albuminous, oleaginous, or saccharine divisions. One set of such are characterised by being coloured, and are on this account employed in the arts by the painter and dyer. The latter divides all these into adjective and substantive colours; the latter embracing all those which, like indigo, for example, have a strong affinity for the fibre of the cloth, and therefore instantly combine with it; while those of the former, not having this affinity, require some base or mordant, which they can combine with, to be added to the cloth. Alumina is most frequently employed for this purpose; but preparations of iron and tin are also used. The combination of the colouring matter with a mordant forms a lake.

The organic colouring matters noticed in this Chapter are:—

I. Those derived from madder.
II. That derived from logwood.
III. „ „ *Quercus infectoria.*
IV. „ „ coccus.
V. „ „ indigo.
VI. Those derived from lichens.
VII. Chlorophyll.

I. THOSE DERIVED FROM MADDER.

According to Decairne, madder root contains one colouring principle only, from which the others are subsequently derived. It is usually stated, however, to contain five, which are as follow:—

1. MADDER PURPLE, OR PURPURINE.

To obtain this, madder roots, after having been well washed with water at 80°, are boiled repeatedly in a strong solution of alum, and the hot liquor filtered. As it cools, a red matter, which is impure alizarine (*see* 2.), falls down. This is separated by the filter, and a clear red solution is left. On adding to this sulphuric acid, the purpurine falls down. It is a fine, crystalline, purple powder, little soluble in cold, but soluble in hot water. It is also soluble in a solution of alum. The colours that it imparts to different tissues have a purple-red tint, and are extremely brilliant. Its formula is not ascertained.

2. MADDER RED, OR ALIZARINE.

This is the red precipitated in the above process, owing to its insolubility in a solution of alum. It is purified by boiling with such solution and repeated crystallisation. It is an inodorous, tasteless, brownish-yellow, crystalline powder. It is very slightly soluble in cold water. It is much used with an alum mordant for dyeing linen and cotton red; with an iron mordant it gives a black; and one variety of it constitutes the famous Turkey red. The formula of alizarine is stated as $37C + 12H + 10O$.

3. MADDER YELLOW, OR XANTHINE.

This is soluble in cold water, and is obtained from the washings of the roots in cold water. It is yellow and uncrystallisable.

The three above colouring matters are separated from one another: the xanthine by virtue of its solubility in cold water, the other two dissolving only in hot; and the purpurine is obtained alone by taking advantage of its solubility in a solution of alum, which cannot dissolve the madder red.

The other two colouring principles found in madder are madder orange and madder brown; both of which are of little consequence, and may be passed over.

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II. THAT DERIVED FROM LOGWOOD.

Logwood contains a colouring principle called hematin, sometimes found in the clefts of the wood, and which may be procured from all parts of the wood by a somewhat complicated process. It is of a brownish-red colour, and with earthy and metallic oxides forms purple, or blue lakes. Acids colour its solutions yellow, and alkalies, purple.

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III. THAT DERIVED FROM QUERCUS INFECTORIA, OR QUERCITRINE.

This may be obtained from this oak by simple decoction, and after a few days it separates in crystals. With the metallic oxides it gives very fine yellow lakes. Its formula is $(16C+8H+9O)+(HO)$.

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IV. THAT OBTAINED FROM THE COCCUS, OR CARMINE.

Several insects of the coccus genus yield carmine, or rather cochineal red. The insects are boiled in alcohol, which extracts it, and then the alcohol is cautiously evaporated. It is a purple-red powder, soluble in water and alcohol. Chlorine makes it yellow, cold alkaline solutions red; with alumina it forms a precipitate which is crimson, if prepared in the cold, but violet when the solution is hot; and it is the former of these that properly constitutes carmine. The metallic salts give lakes with this carmine. Its formula is not certain, but it contains nitrogen.

* * *

V. INDIGO.

This important dye is obtained from several species of indigofera, and also from plants belonging to other genera. As it occurs in the juices of the plant it is a soluble and colourless substance, and may be termed white indigo; but when the plants begin to wither, then it absorbs oxygen, and becomes of a blue colour. When the leaves are noticed to begin to be studded with dark-blue spots, they are gathered by the indigo planters, and are thrown into vats along with some water; fermentation begins, carbonic acid, ammonia, and hydrogen are evolved, and at length a yellow liquid falls down, which contains in solution all the indigo. The *rationale* of this process would seem to be to obtain a solution of the white indigo, which may be gradually oxidised, and thus procured as free as possible from impurities. This solution is then mixed with lime-water, and exposed to the air, and as fast as it acquires it, is precipitated as blue indigo. This, however, still contains many impurities, from which it is freed by repeated treatment with alcohol and dilute alkalies and acids.

Pure indigo is a beautiful blue powder, and its structure, when rubbed with a knife, becomes the colour of copper. It is insoluble in water. Its formula is $N+16C+5H+2O$.

Owing to its insolubility, indigo is of no use to the dyer; but it is easy to deoxidate it, and restore it to its previous white and soluble state. This is done by powdering it, mixing it with slaked lime, and putting the mixture into a solution of protosulphate of iron. In a little the iron salt takes away oxygen from the indigo, becomes persulphate, and the white indigo then dissolves in the lime-water. If cloth be dipped in this, it combines with it; and then the indigo, on exposure to the air, again obtains oxygen, and rebecomes blue.* In practice other deoxidising methods are employed.

If blue indigo be dissolved in sulphuric acid, two acids are formed, the sulpho-purpuric, and the sulph-indigotic. This compound is formed by mixing the acid with it, and the dye is the Saxon blue of commerce. If it is neutralised by an alkali, and any tissue dipped into the liquor, the indigo combines with the fibre of the cloth, and the sulphuric acid, or rather the elements of the sulphuric acid, become again sulphuric acid, and unite with the alkali.

Indigo may be farther oxidated, and new subtances obtained; but into the nature of these, as also into the actions of chlorine upon indigo, it is impossible here to enter.

VI. Colouring Matters obtained from the Lichens.

The chemical relations of these colouring organic principles are very intricate. From one lichen, a *variolaria*, a substance can be obtained, by digestion in alcohol, which is called orcine. It is colourless. When exposed to the action of air and ammonia, it acquires nitrogen and oxygen, and is named orcine, or in an impure state in commerce, archil. This with alkalies gives a fine purple colour, as it also does with metallic oxides. By farther oxidation this archil becomes converted into a blue; and when this is done, and chalk and plaster of Paris mixed with it, we have litmus. This litmus consists of the oxidised archil united to the chalk; and as this combination is a very feeble one, it is decomposed by the very weakest acid, and the red colouring of the azolitmine or oxidated archil (for it should have been mentioned that this is red), is set free.

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* It is now believed that the action is more complex than the oxide of iron becoming converted into peroxide, and that there is a decomposition of water. This, however, need not be here entered into.

VII. CHLOROPHYLL.

Under the influence of light plants secrete, but in very small quantities, a green substance, to which they owe their peculiar colour, and which has been named chlorophyll. This substance has not been very much examined.

In some trees, as autumn comes on, this green chlorophyll is substituted by a red or a yellow colouring matter, to both of which names have been given, and their properties somewhat examined.

The various hues of flowers have been said to depend upon various admixtures of but two organic colouring principles; but this is extremely unlikely. In all probability an immense number of peculiar colouring principles exist in particular trees and woods, and remain to be distinguished by future chemists.

A speculation that chlorophyll has some connection with the conversion of starch into wax will be alluded to in Book IV.

CHAP. XVII.

CERTAIN ANOMALOUS ORGANIC PRINCIPLES.

A NUMBER of organic bodies which do not serve for food are neither acid nor alkaline, and which possess no colouring property, are now known to exist. A very cursory notice of these will suffice. Four examples only will be glanced at, viz.—

I. Salicine.
II. Phloridzine.
III. Caffeine.
IV. Quassine.

I. SALICINE.

This exists in the bark of those willows that have a bitter taste. It may be obtained by the action of oxide of lead on an infusion of it. It occurs in white rectangular prisms of a very bitter taste. Its formula is $21C + 12H + 9O$.

It is remarkable for the strange decompositions it undergoes when acted upon by various substances. One may be noticed: if it be boiled with diluted sulphuric acid, grape sugar is obtained, every three atoms of it (viz. $63C + 36H + 27O$) being resolved into an atom of sugar ($12C + 12H + 12O$), and one of a new substance called salixetine, which has the formula $51C+24H+15O$.

* * *

II. PHLORIDZINE.

This exists in the roots of apple and other common orchard trees. It is obtained by macerating the roots in spirit, and then distilling away the greater part of the alcohol, upon which the phloridzine crystallises. Its formula is $21C+11H+8O$. When it is boiled with diluted sulphuric acid, a new principle and grape sugar are produced. If exposed to air and ammonia, in the same manner as orcine, a rich crimson resinous mass is produced.

* * *

III. CAFFEINE.

This substance, remarkable for the large quantity of nitrogen that it contains, exists in coffee and tea. It may be prepared from the former by saturating a boiled infusion of coffee with diacetate of lead as long as a coloured precipitate is thrown down. By filtering and evaporating the filtered liquid the caffeine is obtained crystallised. If it be coloured by impurities it must be boiled with animal charcoal, and re-crystallised. It forms brilliant white needles, of a satiny lustre. Its formula is $2N+8C+5H+2O$.

* * *

IV. Quassine.

This is obtained from the quassia wood, the bitterness of which probably depends upon it. It occurs in small white prisms that have an intensely bitter taste.

CHAP. XVIII.

ANIMAL SECRETIONS.

An animal secretion is a substance separated from the blood of an animal (generally in those pretty high in the scale) at a gland. Some of these that are intended to form part of the bulk and material frame of the body have already been noticed. Those that remain may be divided into two great classes, the one containing all those secretions which are intended to be made of use in the economy, and the other those which are made up of the effete particles of the body, and which are intended to be cast out. These latter are named excretions. In this Chapter we consider the chemistry of those of the first class only, among which we include blood itself. The following are selected:—

I. **Saliva.**
II. **Gastric juice.**
III. **Chyme.**
IV. **Chyle.**
V. **Blood.**
VI. **Milk.**
VII. **Mucus.**
VIII. **Serum.**

I. SALIVA.

This is secreted by the three parotid glands,—organs which are situated near the mouth. 99 per cent. of it is simply water, and the one per cent. of solid matter that it contains is a mixture of carbonate of soda, chloride of sodium, sulphocyanide of potassium, and a peculiar principle, which has been named salivine. This last is soluble in water, and is not coagulated (like albumen) by heat. The saliva also contains a little mucus. Its reaction is alkaline.

The pancreas, a gland in the abdomen, is usually considered as a subsidiary salivary gland; but its secretion differs widely in chemical composition from the saliva, as it contains no sulphocyanide of potassium and no salivine; but it has some albumen which may be coagulated by heat, some saline ingredients, and a little free acid, which latter gives it an acid reaction.

II. GASTRIC JUICE.

This is secreted by the stomach when food is received into that organ. Its chemical composition is 98 per cent. of water, some chloride of sodium, some hydrochlorate of ammonia, a very minute quantity of chloride of iron, some free hydrochloric acid, and a peculiar principle called pepsine. This pepsine has never yet been obtained in a perfectly isolated form, and its formula is not known; but it is essential to the conversion of food into chyme, a subject that will be referred to in Book IV.

III. CHYME.

After the food has been acted on from two to five hours by the gastric juice, it becomes converted into a grey pultaceous mass, which is gradually propelled towards the pyloric end of the stomach. It has always an acid reaction; but little more than this has been ascertained regarding its chemical composition.

IV. CHYLE.*

As the chyme passes from the pyloric end of the stomach into the small intestines it receives the pancreatic juice and the bile, and then gradually separates into a white creamy fluid called chyle, and a quantity of lignine and other non-nutritious matter. The bile, as will be seen in the next Chapter, contains a quantity of free soda. This not only neutralises the acid of the chyme, but combines with the oleaginous part of it, forming a white soap, which is probably the cause of the white appearance of the chyle; and leaves as much free alkali over as gives the chyle an alkaline reaction.

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* Chyle and lymph are always mixed together in the thoracic duct, and it is the mixture of them that has been examined and is described in the text.

Upon chemically examining the chyle, it is found to contain a quantity of oil, derived from the oleaginous part of the food, and of fibrine, albumen, and salts, derived from the albuminous. We are at present ignorant of the state that the saccharine articles of food are in. The following is the result of Berzelius' analysis of the chyle of a horse that had been fed upon oats:—

Dry clot (fibrine) - - -	0·78
Albumen - - - -	4·49
Fatty matter - - - -	1·67
Salts and extract - - -	1·44
Water - - - - -	91·62
	100·

Dr. Prout thinks that he has detected in chyle a peculiar form of albumen, which he names incipient albumen, and which is characterised by not coagulating with heat, unless acetic acid is added. As will be referred to in Book IV., chyle contains globules.

* * *

V. BLOOD.

Lecanu's analysis of blood (which is derived from chyle) is as follows:—

Blood globules - - -	13·30
Fibrine - - - -	·21
Albumen - - - -	6·51
Fat - - - - -	·37
Extract - - - -	·30
Alkaline salts - - - -	·84
Earthy salts - - - -	·21
Water - - - - -	78·02
Loss - - - - -	·24
	100·

The globules contain a colouring matter called hematosine, a dark brown, tasteless, and inodorous mass. Its formula is $(44C+22H+3N+6O)+Fe$. It is combined in the globules with a modified albumen, or gelatine. It is distinguished from common albumen by being insoluble in a saline solution.

The salts found in blood are the following:— Carbonate of soda, chloride of sodium, sulphate of potassa, chloride of potassium, and phosphate of lime and magnesia.

VI. MILK.

Young mammals are always fed during the first part of their existence with a secretion from the blood of their female parent which takes place at the mammæ, or with milk. Milk is a mixture of oleaginous, albuminous, and saccharine principles, along with the same saline substances that are found in the blood. The following table gives the composition of the milk of the cow:—

Caseine (an albuminous principle) -	4·5
Butter (an oleaginous one) - -	3·1
Sugar (a saccharine one) - -	4·8
Saline matters - - - -	·6
Water - - - - -	87·0
	100·

The butter is contained in globules, which, being lighter than the other ingredients, comes to the top, taking with them a small portion of the water, caseine, and sugar, and constituting cream.

For the *rationale* of the mode of separating all these, see App. on Culinary Art.

VII. Mucus.

This is secreted upon the surfaces of the mucous membranes that line the nose, mouth, stomach, &c. It very much resembles vegetable gum, but differs from it in containing nitrogen. It is a thick tenacious substance, and contains the same salts as the blood.

VIII. Serum.

This is secreted by serous membranes, and also exists in blood. It is water holding in solution some albumen and the salts.

CHAP. XIX.

ANIMAL EXCRETIONS.

THE animal excretions noticed in this Chapter are—

I. The Bile.
II. The Urine.
III. The Perspiration.

* * *

I. THE BILE.

This is the excretion by means of which, as will be noticed in Book IV., the system of animals gets rid of a portion of its effete carbon, and all probably of its effete iron. Its chemical composition has been often examined; but it is certain that many of its supposed constituents are products, and not originally contained in the bile. In all probability bile consists of water, free soda, and a peculiar acid, the cholic, which is combined with more soda, forming a soap, the cholate of soda, and a little cholate of iron. It also contains colouring matter.

The cholic acid may be obtained, the essential part of the process consisting in decomposing the cholate of soda, by means of sulphuric acid. When pure it appears a brittle yellowish mass, of a bitter taste. It forms with bases salts, which do not crystallise. Its formula is $42C+36H+N+12O$.

If cholic acid be boiled along with hydrochloric acid, it is converted into two substances, choloidic acid and taurine.

The colouring matter is of a yellow colour in man, but probably by oxidation it may become red or green, and it does sometimes in disease assume these hues.

Bile also contains some salts.

II. Urine.

This excretion is the one that rids the system of its effete nitrogen, and of all its salts, excepting the iron salt. The following is its composition, the last-named ingredient, namely the silica, being accidentally present:—

Water	933·00
Urea	30·10
Lactic acid and lactate of ammonia	17·14
Uric or lithic acid	1·00
Mucus	·32
Sulphates of potassa and soda	6·87
Phosphates of soda and ammonia	4·59
Chloride of sodium	4·45
Sal ammoniac	1·50
Phosphates of lime and magnesia	1·00
Silica	·03
	1000·

1. Urea.

Urea may be obtained by adding to the excretion nitric acid, and decomposing the nitrate of urea thereby obtained by means of carbonate of lead or potassa. But as urea, like ammonia, is, as it were, nearly an inorganic substance, it can be synthetically constructed. This is done by heating one atom of water with one of cyanate of ammonia, when the two combine as follows:—

Aqueous cyanate of ammonia = $(2C+N)+(N+3H)+(HO)$ or $4H+2O+2C+2N$.
Urea is - - - - - - $4H+2O+2C+2N$.

The reaction of urea is neutral. When heated, it is decomposed, and is resolved into carbonic acid, cyanuric acid, and ammonia. At ordinary temperatures pure urea undergoes no change; but if the least quantity of putrefying matter be with it, this acts catalytically, and the urea appropriates some water, and is entirely resolved into carbonate of ammonia, one atom of urea, and two of water, furnishing, as may be seen by a reference to their formulas, two atoms of carbonate of ammonia.*

2. URIC OR LITHIC ACID.

The urine of all carnivorous animals contains this substance; and it is a principal ingredient in the now celebrated manure guano. In order to obtain it in an isolated form, it is best to take the excrement of serpents or of pigeons, to dissolve this in soda, and then decompose the urate of soda by means of hydrochloric acid. It is thus obtained in fine, white, silky, crystalline scales, which are inodorous and

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* Urea.	2 atoms of water.		2 atoms of carbonate of ammonia.
$2C+4H+2N+2O$.	$2H+2O$.	=	$2(N+3H)+(C+2O.)$

insipid, and insoluble in cold, and nearly so in hot, water. It has an acid reaction, and forms urates. Its formula is $4N+10C+4H+6O$.

Uric acid is remarkable for the number of bodies it is resolved into by the action of reagents as, *alloxan*, *muroxid*, &c.

In disease this excretion is liable to many modifications, which will be found detailed in medical works.

III. The Perspiration.

This excretion has been little examined. Its main use is probably to rid the system of a peculiar matter, which varies in different animals. It also contains some salts and a little free acid.

CHAP. XX.

THE INORGANIC CONSTITUENTS OF DIFFERENT PLANTS.

DIFFERENT plants vary very much in the proportion of their inorganic constituents, as they are improperly called; for the salts of a plant are, while the plant is alive, as much a part of the organism, and as obedient to the laws of vitality, as the albuminous principles, &c. As the constituents of the ash of plants are of very great practical importance, it is necessary to state those of the more commonly cultivated ones.

Grain of Wheat. Mean of Six Analyses. (Johnstone.)

Potassa	23·72
Soda	9·05
Lime	2·81
Magnesia	12·03
Oxide of iron	·67
Phosphoric acid	49·81
Sulphuric do.	·24
Silica	1·17

Straw of Wheat. (Boussingault.)

Potassa	9·56
Soda	·31
Lime	8·83
Magnesia	5·19
Oxide of iron	1·04
Phosphoric acid	3·22
Sulphuric do.	1·04
Chlorine	·62
Silica	70·19

Grain of Barley. Mean of Four Analyses. (Johnstone.)

Potassa	13·64
Soda	8·14
Magnesia	7·46
Lime	2·62
Oxide of iron	1·48
Phosphoric acid	38·93
Sulphuric do.	·10
Chlorine	·04
Silica	27·10

Straw of Barley. Mean of Two Analyses. (Johnstone.)

Potassa	6·31
Soda	·61
Magnesia	39·22
Lime	9·53
Oxide of iron	·83
Alumina (?)	1·39
Phosphoric acid	3·08
Sulphuric do.	1·13
Chlorine	·97
Silica	70·58

Seed of Rye Grass. (Johnstone.)

Potassa	4·97
Soda	1·43
Lime	19·24
Magnesia	5·51
Oxide of iron	2·17
Phosphoric acid	19·59
Sulphuric do.	3·24
Silica	43·85

Ash of Turnip. (Boussingault.)

Potassa	41·96
Soda	5·09
Lime	13·60
Magnesia	5·34
Oxide of iron	1·28
Phosphoric acid	7·58
Sulphuric do.	13·60
Chlorine	3·60
Silica	7·95

Ash of Potato. (Boussingault.)

Potassa	59·95
Soda	a trace.
Lime	2·09
Magnesia	6·28
Oxide of iron	·59
Phosphoric acid	11·16
Sulphuric do.	8·27
Chlorine	3·14
Silica	6·52

Ash of Cabbage. (Fromberg.)

Potassa	11·70
Soda	20·42
Lime	20·97
Magnesia	5·94
Oxide of iron	·60
Phosphoric acid	12·37
Sulphuric do.	21·48
Chlorine	5·77
Silica	·75

Ash of Clover Hay. (Boussingault.)

Potassa	35·47
Soda	·67
Lime	32·80
Magnesia	8·40
Oxide of iron	·40
Phosphoric acid	8·40
Sulphuric do.	3·33
Chlorine	3·47
Silica	7·06

Ash of Oak.

Potassa	8·43
Soda	5·65
Lime	75·45
Magnesia	4·49
Oxide of iron	·57
Phosphoric acid	3·46
Sulphuric do.	1·16
Chlorine	01
Silica	·78

The ash of different animals, also, doubtless is very various; but this is of little practical importance, inasmuch as we cannot weigh out and mix the inorganic food of animals as we can that of plants, and experience teaches us that the vegetables used as food do contain the necessary admixture of such.

The relative amount of nutritive matter contained in different animal articles of food is important. Some recent investigations made by Dr. Davy tend to show that fish is much more nutritious than is generally supposed. The following is abridged from that gentleman's table:—

Animal Articles of Food.

Yolk of egg.	(solid portion per cent.)	45·1
Loin of pork	„ „	30·5
Breast of plover	„ „	31·0
Do. fowl	„ „	27·2
Loin of veal	„ „	27·2
Sirloin of beef	„ „	26·9
Leg of mutton	„ „	26·5
White of egg	„ „	13·9
Cows' milk (new)	„ „	11·2

Fish Articles of Food.

Sea trout -	(solid portion per cent.)	41·2
Mackerel -	„ „	37·9
Salmon -	„ „	29·4
Eel -	„ „	33·6
Sole -	„ „	23·0
Dory -	„ „	22·9
Thornback	„ „	22·2
Trout -	„ „	22·5
Charr -	„ „	22·2
Turbot -	„ „	20·3
Whiting -	„ „	21·5
Brill -	„ „	20·2
Haddock -	„ „	20·2
Smelt -	„ „	19·3
Cod -	„ „	19·2

CHAP. XXI.

THE SOIL.

THE soil is that loose and crumbling mass that on those parts of the earth that are not covered by water lies between the undecomposed surface of the rocks and the atmosphere. In it vegetables germinate, and from it obtain nearly the whole of their structures; and yet, notwithstanding this constant abstraction of it, ample means are in force by virtue of which its amount is in no way diminished. It consists of water, various saline matters which are derived from the disintegration and decomposition of what was the outer surface of the rock upon which it lies, the various acids (described in Chap. VI. as constituting humus); ammonia derived from putrefaction of vegetable, and particularly of animal bodies, and forming salts with the just mentioned acids and nitrates, the nitrogen of which is in part derived from the atmosphere. All these, with the exception of the water, the source of which is evident, demand a little attention.

Of the manner in which the chemical and mechanical arrangements of the elements in the hard rock are altered, so as to be converted into crumbling soil, so much is quite plain:—If the rock is at all porous, and the greater parts of rocks are more or less so, water filters into their fissures. As the temperature falls so that this fluid congeals, the expansion cleaves them into fragments. When the thaw comes on, many of these fragments will be carried away by the torrent, and the rubbing that they are exposed to will convert them into perfectly minute particles.

But, independently of this, most rocks when exposed to air, to moisture, even in the state of vapour, and to carbonic acid (*i. e.* when exposed to common atmospherical air), crumble down, in consequence of their forming new chemical relations. The iron becomes more oxidated, and the other elements — why in our existing knowledge it is difficult to say — leave their crystalline states of combination, and become as we find them in soil. When felspar, for example, is thus exposed, a portion of the potassa forms a soluble silicate, which is partially washed away, leaving a hydrated silicate of alumina, or clay. There are, however, some species of rock which scarcely decompose at all, and such are particularly appropriated for building purposes. Even these, however, if reduced to powder, as by frost and subsequent river carriage, so as to expose a greater surface to the action of the air and moisture, eventually undergo this change.

Of course these constituents of the soil, derived from the crumbling rock, are the same as those which formed the rock. Thus, if we take a soil formed from granite, we expect to find the constituents of mica, quartz, and felspar; *i. e.*, silica, alumina, lime, magnesia, potassa, soda, and oxide of iron. These are readily found; and, in addition, there is phosphorus and sulphur, which are doubtless contained in the rocks; although they are generally omitted in the analysis. See p. 303. *et seq*. Vol. I.

It is not very easy to state in what form these elements are exactly combined. As combined in the hard rock they form compounds which are insoluble in water, and they probably pass through a series of changes until they become soluble in that fluid, just as we saw the insoluble lignine pass by gradations into the soluble apocrenic acid. When they have (with the exception of the alumina, which serves a chemical and mechanical end, and is not a food for plants) become so, plants can take them up and convert them into their structures.

As long as the soil is sufficiently thin, so as to admit the rain that falls along with the air to pass through, the disintegration of the rock on which it lies goes on; and in general these soluble elements are in this way restored to it as fast as they can be carried away by *ordinary* cropping.

A certain portion of existing soils—at least such as have been little tilled—contains soda, &c., derived from sea-water, most of the present terrestrial surfaces having been at one time submerged. But in these, if long cropped, the salts derived from this source are very soon carried away.

Along with these ingredients obtained from the rocks, existing soil contains lignine and the various acids derived from its oxidation, as fully described in Chap. VI. of this Book.

There is also ammonia, obtained from the decomposition of organic bodies, and united, probably, with the humic acids, and also with nitric acid.

This nitric acid is probably derived from the atmosphere. Some of it is formed by the direct union of nitrogen and oxygen (under the influence of electricity), and washed down upon the soil by the rain that generally accompanies a thunder-storm. But whenever putrefaction is going on, a catalytic action is probably excited, under the influence of which some of the nitrogen and oxygen of the air unite, form nitric acid, and join with some of the alkalies of the soil, and thus constitute a nitrate. In this manner, although nitrogen, obtained of course from the soil, is constantly being sold off a farm and not restored by the cities to which it is sent, yet still the quantity of nitrogen necessary to render the soil fertile (*i. e.* to afford to plants matter out of which to make albuminous proximate principles) is kept up.

According to the nature of the rocks from which they are so largely formed, soils vary in their chemical composition. Moreover, the quantity of humus, ammonia, and nitrates may, from causes that are very evident, be deficient. Hence, in practical agriculture, the importance of analysing the soil of a field. The two following tables represent the constitution of two soils; one a remarkably fertile one, the other a piece of moor on which no vegetation could grow. Both are copied from Johnstone's Lectures.

	No. 1. A fertile Arable Soil in Moravia.	No. 2. A barren Moorland Soil in Friesland.
Silica	77·209	70·576
Alumina	8·514	1·050
Oxide of iron	6·592	·252
Lime	·927	trace.
Magnesia	1·160	·012
Potassa	·140	trace.
Soda	·640	do.

	No. 1. A fertile Arable Soil in Moravia.	No. 2. A barren Moorland Soil in Friesland.
Phosphoric acid	·651	trace.
Sulphuric do.	·011	do.
Chlorine	·010	do.
Humic acid *	·978	11·910
Insoluble do. *	·540	16·201
Organic matter, containing nitrogen (*i. e.* ammonia and nitric acid)	1·108	none.

The *sub*soil of No. 2. contained the ingredients, save the ammonia necessary to make it fertile; and bringing them to the surface, and adding decomposing animal matter from without, would of course make it productive.

Thus the soil may be said to stand midway between matter thoroughly dead and thoroughly alive. The crumbling surface of the primeval rock yields up its elements to it, and the surrounding atmosphere ministers to its wants. From it the whole vitalised creation, all animals and all plants, obtain by far the greater part of their frames; but, in that continual Phasis of Matter that is so persistently going on, these frames return to the soil from whence they sprung, and that which was dust, but which has ceased to be dust, becomes dust again.

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* These two were probably acids of the ulmic, geic, &c.. acids' group.

BOOK IV.

THE

CHEMISTRY OF LIFE,

OR THE

CHEMICO-PHYSIOLOGICAL LAWS OF ANIMAL AND VEGETABLE LIFE.

CHAPTER I.

CHARACTERISTICS OF VITALITY.

A LIVING being, whether an animal or plant, may be defined to be an assemblage of various elementary substances which have been derived from the soil and the atmosphere, but which does not obey the laws of mechanics or of common chemistry, but those of an altogether distinct science, to which the name of vitality or life may be given. All these living beings, instead of, as is the case with crystals or rocks possessing a homogenous structure, are provided with *organs* which perform varied but definite functions. Thus the leaf of an oak takes in carbonic acid from the atmosphere, and gives out oxygen, and its rootlets absorb potassa, &c., from the soil; or, the stomach of a sheep digests turnips, and converts them into chyle or incipient blood, and so forth. This possession of organs is so striking and important a peculiarity of living beings, that it is very common to call such living beings organic beings, to distinguish them from the associations of the very same elements in the dead world of, rocks, &c., and the objects of which are called inorganic.

All the organic or living beings are farther characterised by a certain succession and assemblage of phenomena. Three of these are common to every one of them. 1st. They all have their origin from a previously existing and similar structure, or are generated. Thus, an animal is originally derived from its parents, an oak from an acorn that had previously formed part of the tree's living structure; and so in like manner is the case with every other one. And the inference to be drawn from this is, that the creation of the first individual of every genus of animals and plants was owing to a miraculous interposition of Omnipotence. 2dly. The germ derived from the previously existing structure is always very minute; but it acquires matter from without, which it has the power of appropriating and assimilating, or it has the power of forming and keeping up its various organs. 3rdly. This power of assimilating matter, and making it when assimilated obey the laws of vitality, is invariably after a time lost; that is to say, all organic beings invariably end in death, — their organs and structure are gradually destroyed, and the elements that form them return to the world of chemistry and again obey her dictates.

All these living beings may be arranged into two great divisions — of vegetables and of animals. The distinctions between the two are:—1. That the matters derived from without, or the food as it is called of vegetables, is derived from matter subject to inorganic chemistry as situated in the soil (and the air); while the digestive organs of animals cannot appropriate such, but require them to be previously passed through a vegetable, and by that vegetable's vital powers to be combined so as to form gluten, oil, and the other proximate principles described in

Book III. 2. While vegetables go on to the day of their death enlarging their structure and bulk by the appropriation of matter from without, they never, with one important exception, cast off any part of their structure; while in animals, a portion of every element composing them, is continually dying, becoming poisonous to its former possessor, and being, therefore, excreted from the system. 3. Plants have no nervous system, while animals have; and animals have usually the power of locomotion, while vegetables are commonly fixed to a spot. But in some of the lower animals no nervous system has as yet been absolutely detected, and some of them are fixed to a spot; while some vegetables have the power of changing their place. And, 4., Plants contain cellulose; a proximate principle never found in animals; while, on the other hand, animals can convert some of their food into gelatine, which is never found in plants.

There are several very important characteristics with regard to the structure of all organised beings. Thus, the proximate principles formed in them never crystallise, although composed of elements that do form crystals when not in a living body. The only kind of exception to this is when a portion of their structure is in the act of passing on to the dead world, as in, for instance, urea. Then, although we know that the proximate principles described in Book III. do exist in animal and vegetable structures when they are only just dead, and although we know their composition, we cannot synthetically construct them, the only exception again being urea. Moreover, we cannot, by taking and combining these principles, construct an organ, as a leaf, a liver, or the like.

Farther, besides not presenting the plane surfaces and angles of crystalline forms, organic structures have essentially more variety of materials than inorganic compounds. They are all, however, produced from a membrane which is at first only a simple cell; and all organic beings invariably contain in their interior cavities which contain fluids of the same composition as the solids that secrete them, and these fluids during life are in motion.

In order that organic identities, animal or vegetable, may display their peculiar and vital properties, certain conditions must be present. If one or more of them are absent, then death occurs, and the elements return to the control of inorganic and crystalline matter; and in fact it is owing to the absence of some one of these conditions, as will hereafter have to be noticed, that death does take place in any of them. The most important of these conditions are the following:—

All organic beings must possess a nutrient fluid, which is constantly circulating through all their parts, and constantly parting with its constituents to every organ. This fluid is called sap in vegetables and blood in animals, and the stoppage of its circulation is fatal; the length of time, however, during which its cessation may be borne with impunity varying in different genera. This continual parting of the constituents of the nourishing fluid implies a constant supply from without, and this supply is another essential condition of vitality. As before stated, this supply is taken by plants directly from the inorganic world, and the elements composing it can only be so taken when they are in such a state of combination as to be soluble in water. The supply of animals is taken from vegetables (either directly, or as animal food, which has been obtained from vegetables), and both too must also be taken along with water. Another condition is, that this food when taken from without is not at once applied to the different parts that require nourishing, but it is mixed with some existing sap or blood, and has its chemical relations entirely altered or assimilated to such. Farther, this nourishing fluid must be frequently exposed to the air; the sap to appropriate carbonic acid and give out oxygen, and the blood to appropriate oxygen and give out carbonic acid: and the result of these two processes is, that the atmosphere always contains the same quantity of oxygen and carbonic acid, that which plants abstract being restored by the animals, and *vice versâ*.

Heat and light are also essentially necessary to vital action; but their influence belongs more exclusively to the general physiologist, and may be here omitted. It will, however, be necessary to consider the more important of the natural divisions of some of the vital beings.

As before mentioned, all vital structure is originally a cell. To the original cell more are added, and the membrane thus formed is gradually transformed into the various organs of the structure. Some of the lowest plants, however, are never, even when they attain their most perfect form, composed of anything else than cells. The common name of these is the cellular; familiar examples of which are mosses and fungi. *Fig.* 118. shows the structure of one of these, and *fig.* 119. is meant to give an idea of how they increase in size. The basis of all these cells is cellulose, but they also contain many other principles, and, moreover, they possess the sap which of course contains all those chemical elements of

Fig. 118.

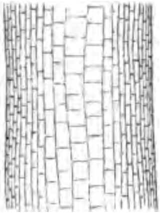


Fig 119.

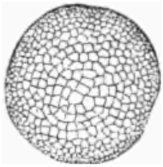
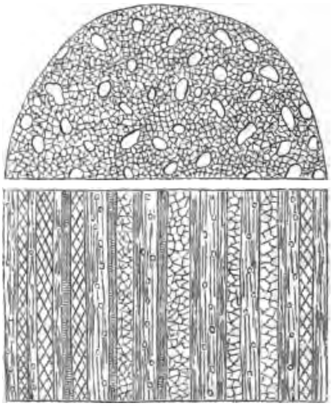


Fig. 120.

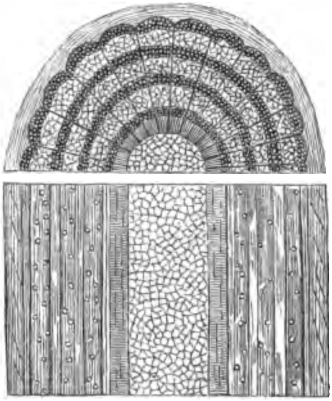


which the structure of the plant and its various secretions are to consist.

Next to these may be ranked the endogens, or plants which are mainly composed of cellular tissue, but among which a few vessels run, and which have probably been produced by the union and partial fracture of a number of cells. *Fig.* 120. illustrates their structure. It is proper to add, that a very young endogen possesses no vessels, and is in fact a cellular plant.

The highest plants are named exogens, and they contain a great number of vessels, and, moreover, a curious arrangement of cells, running from the centre to the circumference, called medullary rays. The appearance presented by the stem of an exogen is

Fig. 121.



indicated in *Fig.* 121. When very young, however, an exogen resembles in its structure an endogen, and when younger still, or an embryo, it has no vessels at all, and is simply a cellular plant.

In like manner, in animals, the higher of them possess a much more highly developed vascular system than the lower have; but even in them the embryos possess no vessels, and merely consists of a few cells.

CHAP. II.

THE SAP AND BLOOD, AND THEIR CIRCULATION.

THE constitution and reactions of the sap of plants are subjects regarding which there is great difficulty and obscurity. Still we are now able to have clearer ideas regarding them than was possible a few years ago. Perhaps the best plan of obtaining a notion regarding them is to consider what takes place in a particular plant, say an apple-tree; and we will suppose that this apple-tree is in the midst of summer, and that (although practically this is absurd) it has flowers, unripe apples, and ripe apples upon it.

The greater part of the wood, bark, and vessels of the apple tree is composed of cellulose (carbon and water), some albuminous principles (nitrogen, carbon, oxygen, hydrogen, potassa, soda, phosphorus, &c.), and a little oil (carbon, oxygen, hydrogen); the bark also contains chlorophyll (a non-nitrogenous matter); the flowers contain cellulose and wax; the partially ripened fruits malic acid, starch or dextrine, and some albuminous matter; and the ripened fruits, besides the acid and albumen, possess sugar; lastly, upon a crack in the bark there will likely be a little gum.

We will farther suppose that for the last twenty hours the nutritive functions of the plant have been exercised with great activity, that the tree has increased in size, that new cellulose and albuminous matter have been deposited in its structure, new chorophyll in its bark, that new flowers have been produced, that some of the flowers have passed into unripe fruit, and that some unripe fruits have become sweet, and also that a little more gum has been secreted. All this implies the addition to the tree of a great deal of carbon, nitrogen, oxygen, hydrogen, potassa, soda, phosphorus, &c., all of which have been obtained from the sap. We will last of all suppose (although this is never literally the case) that during this twenty hours the sap has received no additions to it, and has therefore become much diminished in quantity.

The manner in which the apple tree would proceed is pretty nearly as follows:—The extremities of the rootlets have no epidermis, and can absorb the soluble parts of the soil; but, in all probability, the manner in which they effect this is by secreting cells, which take up the matter of the soil; and it is likely that fresh cells are developed from germs, until the one most in advance comes into contact with the particular elements which the sap requires, in order to restore it to its perfect state. At least this appears to be the only manner in which the selecting power of the rootlets (which power certainly exists) can be explained. The cells having acquired what is needed, are taken into the sap at the extremity of the root.

The substances thus taken into the sap, along with water, are probably apocrenate of ammonia, nitrate of ammonia, carbonic acid, the product of the conversion of humic acid into apocrenic, and (but in very small quantities) silicates, sulphates, phosphates of potassa, soda, magnesia, lime, and oxide of iron, and chlorides of potassium, sodium, and magnesium.

Whenever these salts, however, enter the sap, their chemical affinities fall into utter abeyance, and new compounds are formed. The apocrenic acid (and the carbonic, along with some water) furnishes dextrine, which is the base of sap, and the nitric acid and the ammonia form albuminous compounds, to which the potassa, sulphur, &c., attach themselves. Of the manner in which the elements of the soil so arrange themselves as to form the compounds of the sap, an explanation cannot, perhaps, in the present state of our existing knowledge, be given. It may, however, be said, that it is a vital one, and not one of chemistry. Chemical affinity is that tendency to motions of different elements when placed near together, and when not under the influence of life. Vital affinity entirely supersedes this affinity, and produces new motions of her own, one of the results of which is new products and new compounds.

The sap of our supposititious apple-tree thus recruited begins to ascend the trunk until it reaches the leaves; it passes along the vessels, probably also from cell to cell, but most abundantly through the alburnum. A portion of its water is exhaled through the bark, but when it arrives at the leaves a still greater quantity of water is cast off, and also at the surface of the apples. Another very important change takes place at the leaves, and a large quantity of carbonic acid is taken into the sap from the atmosphere, and oxygen is evolved.* This last phenomenon will be considered in Chap. III., on Respiration. The sap, now in a state of full perfection, then flows to all parts of the tree; to the bulk of it the dextrine supplies its cellulose, and its albumen the albuminous principles. The dextrine yields chlorophyll to the leaf, wax to the flower, malic acid to the immature apple, sugar and albumen to the ripe ones, and at a crack in the bark the dextrine is converted into gum. The probable manner in which these transformations take place will fall to be considered in the Chapter on Nutrition. Lastly, the exhausted sap descends the tree to be recruited by fresh supplies at the root.

That the above account of the course of the sap and of its supplies is the correct one is certain. That apocrenate of ammonia and saline substances are taken from the soil by vegetables in ordinary cropping, is now by British chemists nearly unanimously believed. The farmer is continually adding them to his soil, and yet his soil does not increase in quantity. Nay, sometimes when he manages unskilfully and overcrops, he abstracts these so rapidly, that there is not enough of them left to supply the sap of a full crop, and his land becomes "out of heart." Then while we see that the sap acquires the apocrenate of ammonia, &c., from the soil, we see the vegetable increase in cellulose, albumen, sugar, acids, &c. (all substances that contain the same elements as the apocrenate of ammonia and the like); although we cannot understand how it comes about, that in the organism they are arranged differently; and, further, there is no other source from which the plants can derive these principles that form their bulk save from those indicated. Then, that the leaves take carbonic acid from the atmosphere, give out oxygen, and also water, and that the sap ascends and descends in the manner described, are all easily demonstrated by actual experiments, all of which will be found described at length in books upon botany.

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* The formation of a little carbonic acid also from the sap is here passed over.

In order that the sap may circulate in plants, both heat and light in considerable intensity must be present. When both these influences are acting strongly, as in spring and summer, the circulation of the sap is performed with great force and vigour. If, for example, a vine (in spring) be cut across, and a piece of bladder tied over the stump, the bladder soon becomes tightly distended by the ascending sap, and ultimately bursts.

The causes of the flow of the sap belong to physiology, and in a work of this kind can only be hinted at. Organic structures have a peculiar power of contractility upon being touched by various agents or stimulants. Thus, as we shall immediately see, the hollow muscle called the heart of the higher animals when blood enters it contracts, and by force of that contraction propels the blood. Nothing like a heart exists in any vegetable; but in the highest or vascular plants, such as our apple-tree, the vessels *may* contract upon their contents and assist in propelling the sap. But their influence in this manner is probably extremely slight, and the movements of the sap in the higher plants is nearly, as in the lower it is entirely, dependent upon vital affinities and attractions that exist between the sap and the various structures of the plant through which it flows. Just as the apocrenate of ammonia, whenever it enters the sap, loses its chemical properties and becomes converted into dextrine and albumen, so this dextrine and albumen is not obedient to the ordinary laws of gravitation, and flows in directions altogether different from those which it would do were it mere dead matter.

The blood in animals, in its nature, office, and circulation, is analogous to the sap of plants; from which it mainly differs in being recruited not by inorganic but by organic matter, and in taking oxygen from the air, and giving out carbonic acid. As animals, too, are generally endowed with the power of locomotion, and therefore unable to be always receiving food in the manner of plants, they are provided with a stomach into which they can stow and carry about with them as much food as will keep the organs that are pouring it into the exhausted blood pretty steadily occupied. Moreover, the conversion of food into blood is more gradual than that of inorganic matter into sap, an intermediate fluid or chyle being produced, although it is now believed that the extent to which this is done has been overestimated. But the change in the affinities that occurs between the food and blood is by no means so great and remarkable as between food and sap.

The various changes that occur between the reception of food and its conversion into chyle may here be omitted. In this place we will only consider the manner in which the exhausted blood obtains new supplies from the chyle, the mode in which it is circulated, and the changes which it undergoes during that circulation.

The organs of circulation in man and the higher animals are the heart, the arteries, the veins, the capillaries of the body in general, and the capillaries of the lungs; and those concerned in conveying the assimilated food or chyle to the exhausted blood are the villi of the alimentary canal, the lacteals and the thoracic duct. Any lengthened account of these is in this work out of the question; but still a general idea of them is necessary in order to understand the Phasis of Matter as far as regards the conversion of food into blood, and of blood into the various structures that compose the bulk of the body.

The heart is situated between the lungs, in the cavity called the chest. It of a somewhat conical form, its base being directed backwards, and its point or apex forwards, downwards, and to the left side, where it may be felt striking against the sixth rib. The great blood vessels arise from its upper extremity. In *fig.* 122. these great vessels, the heart, and the lungs are represented.

The human heart contains four cavities, called the right and left auricles and ventricles. There are in fact two hearts joined together, each of which consists of one auricle and one ventricle; the one situated at the right side being for sending the blood to the lungs to be exposed to the air, and the other at the left side being for sending the blood to the different parts of the body for the purpose of nutrition. In each of these, between each auricle and ventricle, there is a valve which, while it facilitates the flow of the blood from the auricle to the ventricle, effectually prevents any regurgitation from the ventricle to the auricle. Both auricles and ventricles are strong muscles; the latter, however, being by far the stronger. *Fig.* 123. represents the cavities, valves, and great vessels connected with the heart.

Fig. 122.

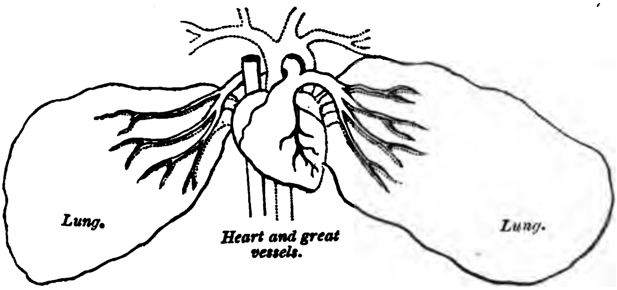


Fig. 123.

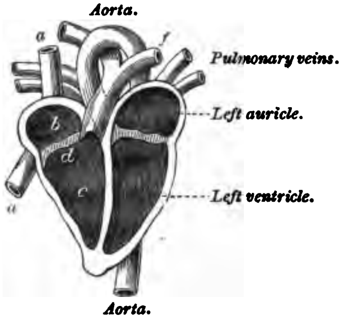


Fig. 123. will also illustrate the manner in which the valves of the heart act. It is a section of the right auricle and ventricle; *a a* are two large veins called *venæ cavæ,* which convey the venous blood, which has been returned from the various parts of the body, into the auricle *b.* The auricle contracting upon the blood which it has received squeezes it into the ventricle *c,* through the orifice *d.* Upon each side of this orifice a membranous fold is seen, both of which are kept in their places by means of the tendonous chord *e.* As long as the blood is flowing from the auricle to the ventricle these folds yield readily to the current; but whenever the ventricle, being full, begins to contract, the blood presses against the under side of these folds, and causes them to close against one another, so that the blood is propelled into the pulmonary artery *f.* The other side of the heart, the aorta, and also the veins are provided with equally effectual valves, which prevent the regurgitation of the blood.

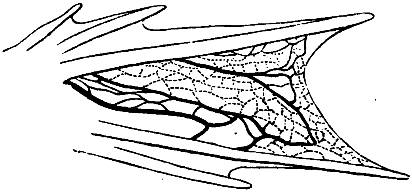
The arteries convey the blood from the heart to the capillaries. These arteries are flexible and elastic tubes, cylindrical, and very strong. The whole arterial system springs from the aorta, which originates in the left ventricle of the heart. The branches of it divide and subdivide as represented in *fig.* 124. These branches have very frequent communications with one another by means of numerous anastomosing subbranches. Each time that the left ventricle contracts it drives a jet of blood into the arteries, and this rush of blood may be easily witnessed in the larger arteries, and is familiarly known as the *pulse.*

From the arteries the blood passes into capillaries.

These are a set of very minute vessels that form a network which is found in nearly every tissue. These capillary vessels correspond very much with the cells of plants, and in them nutrition and secretion take place; and it is likewise in the capillaries of the lungs that the venous blood is exposed to the air. *Fig.* 125. represents the capillaries in a translucent animal. When the blood has performed its functions in the

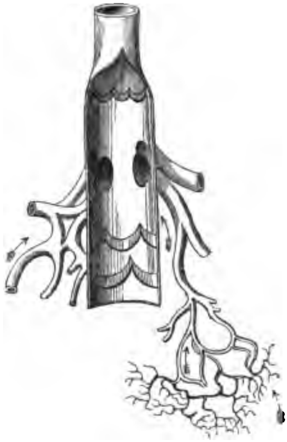
Fig. 124.

Fig. 125.



capillaries, it is gathered up by small veins. These small veins unite to form larger ones, all of which at last centre in the two venæ cavæ which convey the venous blood to the right auricle of the heart. In *fig.* 126. the union of the veins, and also the valves of the veins, which prevent any retrograde motion, are seen.

Fig. 126.



The blood in the arteries is of a scarlet colour, and contains oxygen, and also a greater amount of nutrient matter than the venous. In the capillaries it parts with this oxygen and nutrient matter, and acquires carbonic acid, &c., and this venous blood is of a red colour.

To recapitulate, the blood in the capillaries gradually makes its way to the smaller veins, and along them, passing from those that are smaller, but more numerous, to those that are larger and less numerous, until it reaches the right auricle of the heart. By the contraction of this auricle it, the blood, is driven into the right ventricle, which by its contraction draws it into the pulmonary artery. Flowing along this, it reaches the capillaries of the lungs to be exposed to the air. From these it passes through an ascending series of vessels to the pulmonary veins, which conduct it to the left auricle of the heart. This contracts upon it, and drives it into the left ventricle; which again propels it into the aorta, by the numerous branches of which it is carried into the capillaries.

That this is the true account of the circulation of the blood is unquestionable. The venæ cavæ, the auricles, and the ventricles have in cases of injury been seen to be distended, and to contract in the order stated. Then in translucent animals the blood may be seen to pass from the capillaries to the veins, and from the arteries to the capillaries. Indeed, the structure of the valves of the heart and veins are so constructed that, while they promote the flow of the blood in the manner that it is thus described to flow, they render it impossible for it to flow in any other direction. Lastly, if a ligature be placed around an artery, the artery swells between the *heart* and the ligature; whereas, if it be placed around a vein, the vein swells between *capillaries* and the ligature.

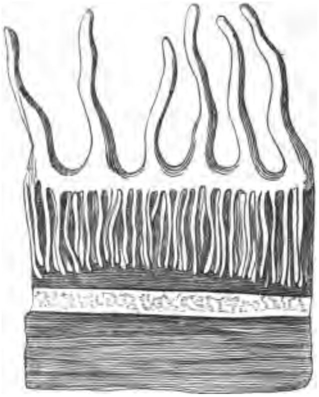
The causes of the movements of the blood are partly the contractions of the heart, but still more the vital affinities that exist between the blood and the different living structures.

The blood is continually parting with its albuminous and other principles in the arterial capillaries. In order to keep up the blood in a state of integrity, it must as continually receive fresh supplies; and this it does in the shape of food. This food, consisting as it does of albuminous, oleaginous, and saccharine proximate principles (*i. e.* of exactly the same chemical constituents as the blood), is very suitable for recruiting the exhausted fluid. A portion of these proximate principles of the food are (it is now known) added directly to the blood, and are absorbed by the blood-vessels of the stomach and duodenum. Another portion (and until quite recently this was believed to be the case with all of it) is very gradually added to the blood, and is previously assimilated with existing animal principles. The following is what takes place:—

That portion of the digested food called chyle is pushed by the contractions of the stomach into the duodenum, as seen in *fig.* 127. The mucous membrane of this is covered with minute villi, or little projections, that exactly correspond with the spongeoles of plants. These during digestion secrete little cells which absorb the chyle, and then in some manner or other deliver the digested food to the lacteals that originate in these villi. The chyle passes on through the mesenteric glands until it is delivered into the thoracic duct. Here it is mingled with the contents of the lymphatic vessels, and the mixed fluid is then poured into the blood at the junction of the right jugular and subclavian veins.

Fig. 127. represents a magnified view of a little bit of duodenum.

Fig. 127.



The above account, it should be observed, is only true with regard to the higher animals, and in the lower the food is added at once to the blood.

This seems the proper place to notice the lymphatic system, and absorption in general in animals. Interstitial absorption (*i. e.* absorption in a living being of its own structures) is peculiar to animals. It is partly, perhaps, subordinate to the gradual assimilation of the food with the blood; but its main end is to take up those different parts of the frame that have become effete, and to add them to the blood, that they may be turned into the different excretions, and cast out at the proper organs. In the lower animals there are no special absorbent vessels, but the matter is managed by the blood vessels. Indeed, in the higher the veins are actively employed in absorbing; but there are a peculiar set of vessels also, the lymphatic, which, arising from nearly every part of the body, at length centre in the thoracic duct.

CHAP. III.

RESPIRATION.

Respiration is a function subordinate to the digestion and assimilation of the food, and is the name given to that process by which the nourishing fluid of animals and plants takes in something from the air, and also pours out an excretion into it. In the case of animals the substance taken in from the air and added to the blood is oxygen, and the substance given out is carbonic acid. The very reverse takes place in plants, and carbonic acid is taken in by the sap while oxygen is excreted. It is principally in this manner that the purity of the air is preserved; and the carbonic acid, which, if allowed to accumulate, would extinguish animal life, removed from it.

The respiration of animals would appear a more complicated process than that of vegetables. The variety of arrangements and adaptations of the respiratory or breathing organs in the different animals to the degree and mode of action of the air upon the blood is very interesting. Animals low in the scale of nature, and having a simple and uncomplicated structure and a porous body, have no separate breathing apparatus. Either air or water impregnated with air enters into all parts of their bodies, and acts upon their blood. For example, in the radiate animals the air contained in the water in which they dwell acts upon all the surfaces of the body.

Among higher animals whose textures are more complicated, and whose structure is likewise dense, a separate breathing apparatus is provided. The nature of these mainly depends upon the intensity of the vital actions that are to be performed, and upon the medium, air or water, in which the animal is intended to live. Thus animals which, like mammals or birds, are destined to perform intense vital actions, to be warm-blooded and to inhabit the air, have what is called a double circulation. That is to say, all the blood which has been circulating through the body to nourish it, and to obtain carbonic acid, is sent to the lungs, to be there exposed to the air before it is again allowed to be circulated. When an animal inhabits air, but has less active vital functions to perform, as indicated by its cold blood, it also breathes by means of lungs; but its circulation is what is called single, *i. e.* only part of the blood which has circulated is sent to these lungs, and this part, after having been exposed to the air, is mixed with what returns from circulating in the body. Those animals that inhabit the water have not lungs, but gills; *i. e.* membranes containing blood-vessels growing from the surface, and not enclosed in a cavity. In these gills the blood only acts upon the air which is mechanically mixed up with the water, and, as may easily be supposed, the action that takes place in them is much less than that which happens at the lungs. Hence it is that fishes, although they have a double circulation, are nevertheless cold-blooded.

In men and the higher animals the first step in the process of respiration is a sensation in the chest felt immediately after expiration, and which, if not relieved by taking in air, soon amounts to absolute agony, and always excites to acts of inspiration, which inspiration quite relieves it. This sensation depends upon venous blood, containing carbonic acid, being present in the capillaries of the lungs, and which has been sent there by the contractions of the right side of the heart. Other sensations besides this one also excite to acts of inspiration, as, for instance, the sensations produced by throwing cold water upon the face, or applying pungent odours to the nose.

This sensation is conveyed to the brain by a nerve, and when it is felt an influence is sent from the brain through the motor nerves of the muscles concerned in respiration, which causes them to contract. The result of these contractions is to expand in all directions the cavity of the chest. When the chest is thus expanded a vacuum is formed, and the air rushes in through the windpipe, and parts with its oxygen to the venous blood. In this way the blood gets oxygen.

The venous blood likewise parts with the carbonic acid that it contains, and this, along with the nitrogen of the decomposed air, watery vapour, &c., is expelled by the act of expiration which succeeds to that of inspiration. The average quantity of carbonic acid given off from the lungs of a healthy man in twenty-four hours has been calculated at 40,000 cubic inches. These would weigh three pounds, and contain eleven ounces of pure carbon. The quantity therefore of carbonic acid thrown into the air every day by animals must be enormous.

The respiràtion of plants, save in the important difference that carbonic acid is taken in and oxygen given out, is very identical with that of animals. In the lowest plants, as in the lowest animals, no special organs are provided at which the interchange may take place, but the function goes on at the general surface. In the higher plants special organs (analogous to the gills of animals) or leaves, are provided. When exposed to the light of the sun, these leaves absorb the carbonic acid of the atmosphere, and add it to the sap. During the course of the circulation the vital forces decompose this carbonic acid, and the carbon is retained as part of the plant's structure, while the oxygen is conveyed back by the sap to be cast out into the air.

It is important to notice that this respiration of plants only occurs under the influence of light. Indeed in the dark, or at least in the dark of the night, some function is carried on in plants, the result of which is plain enough, but the nature of it has been little investigated, in which carbon and oxygen unite and are given off as carbonic acid. The quantity, however, of carbonic acid given out into the air by plants during the night by no means equals that removed from it by them during the day; and so exactly has the absorption of carbonic acid by plants during the day equalled that given out by plants during the night, and also that given out by animals during both day and night, that it is believed that the quantity of carbonic acid present in the atmosphere has neither increased nor diminished for many thousand years.

Intimately connected with the above processes is the heat of animals and vegetable heat. As long as an animal or plant is alive it, as is familiarly known, maintains a higher temperature than the surrounding air, and higher than either of them will be when dead. In other words, living beings have the power of generating heat. Birds possess this property in greater intensity than any other vitalised being, although *parts* of certain plants (as the flower of an arum) exceed them in this respect. Thus, the temperature of a swallow is 112°; the temperature of man is about 100°; some of the lizards can maintain a temperature of 86°; but most of the reptiles, and also almost all fishes, have only a temperature a few degrees warmer than the water. Plants are commonly from 1° to 1½° warmer than the air around them.

The great source of the heat of animals is the formation of carbonic acid that is in all parts of their bodies being formed during both day and night. And a considerable source of that of plants is owing to the formation of that compound that goes on in their structure during night. The heat always produced by the union of carbon and oxygen has often in these pages had occasion to be noticed.

In animals the carbon required for this purpose is either the saccharine and oleaginous articles of food, or, which is more probable, these are assimilated and appropriated to the structures that contain carbon; and when these have become effete, this same carbon is excreted. It is now generally believed that a portion of the bile is not excreted, but used in this manner as fuel.

If, however, we compare the amount of heat generated in an animal with the heat it evolves, we find that the quantity of carbonic acid thrown off is sufficient to account for three-fourths only of the caloric. We have so frequently in the foregoing pages seen heat produced by chemical unions, that we can easily believe that the fourth of animal heat is caused by new vital arrangements of the elements.

The carbonic acid of plants is probably derived from the decomposition of sugar or starch. A great part of this heat, however, is produced by other chemical changes than the formation of carbonic acid.

CHAP. IV.

REPRODUCTION.

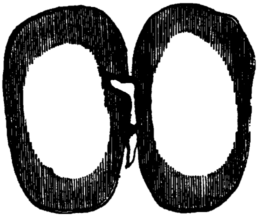
As before mentioned, one of the characteristics of vitality is, that every living being, plant, or animal, must have its origin in a previously living being, or, in other words, must be generated. This function of reproduction has many analogies in the animal and vegetable kingdoms. If a portion, taken at random, of many vegetables, be cut off and placed in the ground, it often takes root, and becomes an independent plant. In like manner some of the lower animals, as, for example, earthworms, may be cut into pieces, and each piece may be developed into a perfect animal. But in higher animals and (normally) vegetables, it is only one particular portion of the existing or parent animal or plant that can be developed into a new one, and complex arrangements are made for the evolution and early support of the young living being.

In the higher or vascular plants there is a distinction of sex. One plant, or one part of a plant, is female, and the other male; and there are male and female organs of reproduction. The female organs have the power of forming within themselves a germ, and the male a substance which, when applied to this germ, fertilises it; and without this fertilising matter the germ remains undeveloped. But when the fertilising matter is applied to the germ, the female organs deposit around it nutritive matter; what is called a seed is formed, and if placed under favourable conditions, this seed (or, more correctly, a portion of this seed) can become a perfect plant.

The changes that take place during this germination of the seed have been well investigated. There is some little difference between common seeds and oily seeds in this respect, but a narration of what takes place in a common seed, as a bean, will be in this place sufficient.

When the flower of a bean has obtained its full size, a pistil, containing ovules or immature germs, surmounted with a hollow tube or pistil, may be seen. This pistil is surrounded by the male organs or stamens, at the extremity of each of which is an anther covered with pollen, the fertilising matter. As the flower becomes quite ripe, the pollen falls off, and the anther descends the pistil, and drops upon the ovules, which then become embryos of future plants. Before the parent, however, casts them from her, a quantity of starch and albuminous proximate principles are deposited around each. The perfect germ or seed, or bean, then falls off. If we split it, as in *fig.* 128., we see the little germ placed between two cotyledons, as they are called; and on analysing these cotyledons we find that they contain about

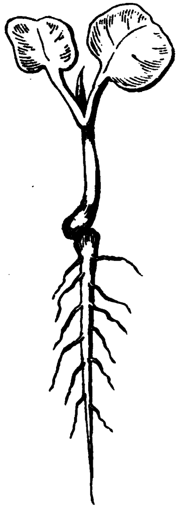
Fig. 128.



twenty-two per cent. of albuminous and nearly fifty of saccharine, of which by far the greater quantity, indeed nearly all, is starch; and, in addition, some three per cent. of salts.

As long as such a bean is not exposed to heat, moisture, and oxygen, its vital functions remain suspended. And as most seeds only ripen during the autumn, their vital functions, even if placed in contact with moisture and oxygen, generally do so remain suspended during the winter. With the warmth of spring, however, particularly if placed in the dark (for all plants tend to exhale oxygen under the influence of light), a remarkable series of changes begin. The upper extremity of the embryo, called the plumule (see *fig.* 129.), extends itself upwards. This is the young plant in miniature; and its leaves and buds, although on a small scale, are often plainly visible. At the same time the embryo increases downwards, and the radicle, or root in miniature, extends itself into the earth.

Fig. 129.



The plumule and radicle have to grow bigger, and to send forth leaves and spongioles, by means of which the plant may obtain carbon from the air, and apocrenate of ammonia, potassa, sulphur, &c., from the soil. In order that these leaves and spongioles may be formed, however, a certain supply of food is necessary from somewhere.

The outside of the cotyledons are generally pushed a little way above ground, and can act as imperfect leaves, and thus obtain a little carbon; but in no other manner can the young plant obtain food from without, and unless some provision had been made for it, it would die of starvation.

The starch and gluten contained in the seed, with the inorganic matter combined with the latter, are amply sufficient to feed the young plant until its spongioles are complete. But they are not so combined in a state as to be soluble in water ; and indeed, had they been so combined, they would likely have been washed away long ago; but unless they do become so arranged as to be soluble in water, they are of no use to the embryo. Accordingly a number of curious chemical relations are made to take place.

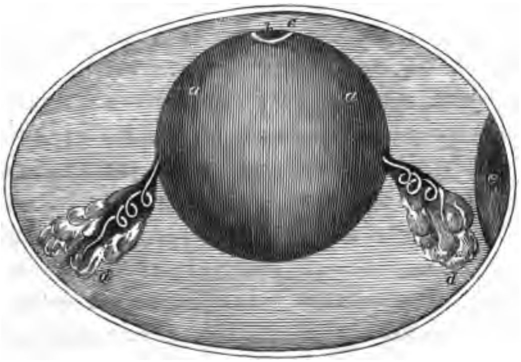
Great heat is evolved contemporaneous with the absorption of oxygen and the evolution of carbonic acid. In all probability this is connected with the transformation of a portion of the albuminous matter into diastase, a substance necessary for germination. This diastase converts the starch into dextrine, then into cane, and lastly into grape-sugar. Also, in some manner that we cannot explain, an atom of water is taken from an atom of a portion of the starch, and thus acetic acid is formed. This probably combines with some of the inorganic matters, and forms soluble acetates. The diastase having performed its catalytic action, is probably added to the juice of the young plant to form albuminous proximate principles. Of course that portion of the carbon of the starch set free to form sugar, joined with the absorbed oxygen, is the source of the carbonic acid that is evolved. By the time that the supply of food contained in the seed is exhausted, leaves and spongioles are formed, by means of which the plant can obtain its food from the soil and air.

The reproduction of the animals is very analogous to that of vascular plants. There are two sexes sometimes, as is generally the case with flowers, united in the same individual. More usually, however, the sexes are separate, as is the case with willows and other monœcious plants. The female organ consists essentially of an ovarium containing inactive germs, which are roused into activity by a secretion from the male. As the impregnated germ of plants is not cast out of the parent system as soon as formed, but, as a store of nourishment is deposited around it, on which to feed until its organs become mature and able to appropriate dead matter from without and also nutriment, so also generally albumen and oil are deposited around the embryo animal. When this has been done, in many races of animals the embryo and its store of nutriment, commonly called an egg, is thrown off by the female parent.

In like manner, too, as the presence of warmth is necessary for the development of the embryo plant into the perfect vegetable, so also, and in the higher animals in a much greater degree, is warmth to the development of the embryo animal. Sometimes the natural heat of the sun is sufficient for this, but at others instinct teaches the parents, and more usually the female parent, to communicate the heat of their own bodies to the egg by remaining constantly, or nearly so, seated upon it.

The changes that take place from day to day in the embryo of an egg are fully described in physiological works, and may here be omitted. *Fig.* 130. will afford an idea of the structure of an egg; *a a* is the yolk, composed of albuminous principles and a little oil, and which exactly corresponds, as far as its physiological action, with the starch of the grain; *b* is the embryo, with a peculiar mark *c*, the actions of which belong to physiology; *d d* are two cords, which keep the germ, or rather germ-bag, in its place; and *e* is a little store of air. For the manner in which the germ lives upon the yolk reference is made to treatises on physiology.

Fig. 130.



CHAP. V.

DISEASE AND DEATH.

All living identities are essentially temporary in their nature. The length of time, however, during which different species of plants and animals maintain their vitality is very variable. The majority of vegetables have an existence of only a few months, and come into life in the spring and perish in the autumn. Others, again, usually continue alive for two years or eighteen months; while some are able to protract their existence over a very extended period. Individual oaks, for instance, are believed to have lived for upwards of a thousand years. The length of life of animals, on the other hand, is extremely variable among the different species. Some insects, for example, have a very temporary duration; a great many of very perfect animals, as the horse, the ox, and the dog, rarely live for more than twenty years; few even of men attain the age of seventy; while some of the birds and reptiles are said to remain alive for a much longer period. But all vitalised structures, whether the sprig of mignonette, or the oak, the ephemeral insect or the tortoise, invariably at last of all perish, and restore to the earth that structure which they derived from it. In ordinary language, this passing away of life is spoken of as having an actual existence, and is called death. Death, however, is merely a negative, and implies the absence of vitality, and, as far as regards our corporeal existence, the apophthegm that "where we are death is not, and where death is we are not," is literally correct.

The cause of this cessation of existence, or the causes of death, are certain improper manners in which vital actions are performed, and which either impede the circulation of the blood or sap, or hinder the exposure of this all-important fluid to the air at the leaves, gills, or lungs. These imperfect manners of performing these functions constitute diseases. The nature, the causes, and the mode of fatal termination of these diseases in animals have been long studied, and a good deal of generalisation has been obtained regarding them. Very little attention has been paid to the diseases of plants and indeed the information we possess regarding them is almost nothing. What little is known will be found in the systematic works upon botany. A great many very learned and able treatises upon the pathology of man and the domesticated animals have been published, and to both these classes of books reference is made. To treat of these matters here is of course quite out of the question; but still in a treatise on the Phasis of Matter a few lines must be allotted to this subject of death, for it is the commencement of that series of changes which, ending in complete putrefaction, restores the elements that have been forming part of a living structure to the inorganic world and the laws of common chemistry.

The circulation of the sap or the blood may be arrested in both animals and plants in a very simple manner. We have seen that these nutrient fluids are continually expending their constituent elements for the purpose of making the various tissues of the animal or plant, and that they consequently require continual supplies of matter from without to make up for this expenditure. If, however, these supplies be not afforded, the sap or blood becomes gradually deficient in quantity, until it can no longer nourish and build up the living body to which it belongs, and which in consequence dies of starvation, as it is called.

From what we have already seen, it will be evident that the absence of any one element in the blood or sap will be as injurious as if the whole were wanting. Accordingly we find practically, that from some cause or other oxide of iron does occasionally not enter at all, or not in sufficient proportion, into the blood of the human species, and that those individuals in whom this occurs become diseased, and if not cured, at last die. In the same manner plants undoubtedly cease to exist from the want of one or two particular elements; and the crops cultivated by the farmers frequently become very much stunted and yield a bad produce, from one or two elements of the food not indeed being absent (in which case the whole crop would perish), but from their being present in insufficient quantity. In practice it is found that the two substances usually deficient in bad or in exhausted ground are nitrogen and potassa. By means of guano and other artificial manures the farmer can remedy the want of the former; and the high farmer does so, although altogether at random and empirically. But no cheap source of potassa in some soluble form is known, and the discovery of such would probably become an era in the history of the art of agriculture.

Another very common cause in animals, and possibly in plants, of the nutrient fluid becoming unable to go on nourishing the structure to which it belongs is imperfect assimilation. Either a sufficient quantity of food (although present) is not taken in, or, if taken in, cannot be assimilated to the existing sap or blood, which therefore soon becomes exhausted. But in the existing state of our knowledge we cannot refer this imperfect power of assimilation to anything but some impaired condition of the vital affinities. However, in animals that are suffering from chronic diseases it is thus that life is almost invariably destroyed.

It would seem, too, that, as living structures advance to the natural termination of their existence; which termination, as above stated, varies in different species. There is a tendency for the plant to form more lignine, and the animal more phosphate of lime; the result of both which is at last to impede the circulation of the sap and blood, and thus to produce death. This is by no means an unusual termination of the existence of even man; and it would seem to be the cause of the immense majority of the deaths of plants. Indeed, it would appear that the ordinary cause of death in an aged animal is the inability to assimilate food, as stated in the previous paragraph; while a plant that dies of old age naturally does so owing to its tendency at last to secrete lignine within its structures.

A very common cause of the death of animals is the hindrance of the exposure of the blood to the air; but it may be doubted if—at least on an extended scale—the similar deprivation of the sap of plants is productive of much disease and death. Such may indeed in both cases be produced either by injuries or by morbid growths disorganising the respiratory apparatus; but the common cause of it in animals is dependent upon an affection of the nervous system which belongs entirely to the province of physiology.

Violent and sudden injuries may bring about these fatal terminations more rapidly, and in a still more striking manner than diseases.

Another cause of death in both animals and plants is the reception into their system of certain substances called poisons. With regard to the mode of action of these poisons we have scarcely any knowledge. Some of the caustic ones destroy life by abstracting the water which is essential to the continuance of the vitality of all living structures, and others again may perhaps act injuriously by coagulating the albumen of the sap and blood, and thus preventing the possibility of its circulation. But beyond these conjectures we know nothing of the manner in which poisons destroy life.

There are a number of poisons generally held to originate either from vegetables or animals, which, however, have never yet been isolated, and which are called miasmata and contagions. Several varieties of them exist; but they all seem to agree in this, that, when introduced into the blood (their action upon sap has not been investigated), they seem to act as ferments, and catalytically become reproduced in it; and when existing in any quantity in the blood, they prevent the due performance of many vital functions, the suspension of which may, and in many cases does, produce death.

CHAP. VI.

THE PUTREFACTION OF DEAD ANIMAL MATTER.

A VERY short time after any of the animal principles described in Book III. lose the remains of their vitality, the bonds that bind their elements together entirely disappear, and their matter returns to the laws of inorganic chemistry. While their elements are forming inorganic compounds, there is generally pretty intense chemical action set up; and to the series of chemical changes that are then taking place the name of putrefaction is given.

This putrefaction essentially consists in the nitrogen of the albuminous proximate principles leaving its alliances and combining with hydrogen to form ammonia; in carbon and hydrogen uniting to form carburetted hydrogen; and sulphur and hydrogen to form sulphuretted hydrogen. It is the last-mentioned substance that communicates the greater part of the offensive smell of putrefying bodies. A portion of the sulphur and phosphorus, if not oxidated before now, becomes sulphuric and phosphoric acids, and form, with the lime, potassa, &c., salts. Lastly, the water, that constitutes so large a bulk of animal textures, trickles away; and what, with the loss of it, and of the gases that have passed off into the air, the bulk of that which is left behind, when the process of putrefaction has ceased, bears a very small proportion to the original bulk of the body before putrefaction began; and this, notwithstanding that during the changes a considerable quantity of oxygen is taken from the air to take its share in the composition of the new compounds that are forming.

Besides the thorough departure of life, certain conditions are indispensable to the process of putrefaction; water must be present in order to give the necessary mobility. Thus, if an animal substance be accidentally or artificially deprived of its water, no putrefaction takes place. For instance, the bodies of those who have perished in the Arabian desert are found, years after, very dry, but quite fresh. In the same manner, if meat be deprived of its water, either by very rapid drying or by extracting the water from it by means of salt, the process of putrefaction is averted. If we freeze flesh also, by rendering the water solid, we avert putrefaction. Then, oxygen must be present, and meat can be kept fresh an indefinite time if hermetically sealed in tin cases from which the air has been expelled.

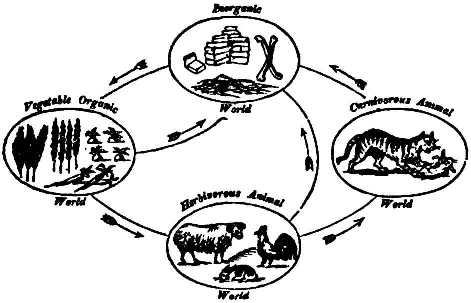
Just as putrefaction is beginning, and before any fetid gas is exhaled, a something, the chemical nature of which is quite unknown, is occasionally generated, which possesses very poisonous properties.

When the conditions favourable to putrefaction are fully present, the process goes on very rapidly, and the body of even a large animal speedily loses all its appearances and structures, and the elements that composed it return to that world of inorganic chemistry from whence they originally came, destined probably very soon to form another living being.

So it is, that as we all sprang either from putrefaction, or from dead matter that has never before been vitalised, so in like manner must all our frames return through the ordeal of putrefaction to the dead world. The muscle of the strong man, the bloom of beauty, the brain of the philosopher, must once more rot, as doubtless they have often rotted before, and are destined, in the continual Phasis and Circulation of Matter, to rot again. The hand that writes this sentence, nay, the very brain that conceives the thought that the hand is marking down, was once earth such as that we all trample on, and soon will be earth again, and, perhaps, ere even the writer's name has ceased to be mentioned by those with whom he holds familiar intercourse, will be transformed into the cypress of the cemetery, or the daisies of the country-church-yard. Nay, also the matter of that eye that reads this saying, and of that brain that receives that saying, and is perhaps startled at it, a little while ago was allied to the elements of inorganic matter; and the time cannot be very distant ere some have to mourn over those terrible words read over it, of "dust to dust and ashes to ashes." The very tear of affection was once water and a little rock-salt, and after a little time it will be water and rock-salt once more. The Phasis of Matter is no idle dream; nor are its operations, although they take in even the minutest of things on a small scale. On the contrary, its truth is unquestionable, and its magnitude almost incomprehensible.

But there is nothing terrible in the doctrine, but the reverse. What is it to us as individuals what the matter of our frames was ten years ago, or may be ten years hence? Matter is the organ of thought, but it is not thought; it is the medium of uniting our temporary physical identities with our souls, but it is not our souls. Ten years ago the hand that pens this sentence did not contain a single atom of matter that it now contains, and yet ten years ago it was my hand. Ten years ago my brain knew and believed those leading principles that are so feebly expounded in this volume; but in that interval the matter of the brain has changed. Not a fibre that vibrated in it then vibrates now, and yet my mind is filled with the same conceptions and the same conclusions. Why a thinking and a spiritual being, like man is temporarily mixed up with matter we know not, any more than we can understand the connection; but we know even with more certainty than that there is matter, that there is mind; and we farther know, that by culture mind may be refined, that knowledge may be accumulated, and that out of increased knowledge comes increased hope.

Fig. 131.



APPENDIX.

THE

APPLICATION OF CHEMISTRY

TO

THE ARTS.

No. I.

RURAL ECONOMY.

There can be no doubt but that at a very early period of society the culture of the soil and the tending of domesticated animals became arts, and that agriculture (for by usage the expression includes now-a-days the rearing and management of stock) was managed in accordance with certain fixed rules that were dictated by previous experience. In the very primitive state of sheep and cattle farming, no assistance, perhaps, was derived from any abstraction or principle of science; but even in the commencement of arable culture or agriculture proper some knowledge of mechanics at least was necessary. But it is only within a very recent period that the science of chemistry has promised to explain the operations of the husbandman, and to direct and improve his future proceedings. Recent, however, as has been that period, the doctrine of the Phasis of Matter, as attempted to be explained in the preceding sheets, renders it possible to raise farming from being a mere experimental and traditionary art to the rank of the most scientific process or series of processes.

The first step in the right direction (although it led to results altogether erroneous) was probably made by Van Helmont. He was struck with the fact, which indeed every man who ever thought must have been struck with, how is it that an acorn, for example, which does not weigh more than a few grains, becomes converted into a large oak that turns the balance against many hundredweights? All that matter which forms these hundredweights of timber and bark must have been derived from somewhere. Van Helmont endeavoured to decide the question experimentally; and chose the willow to experiment upon. He came to the conclusion that the growing plant derives its nutrition, *i. e.* its structure, from water, and that water is by some physiological process converted into stem, leaves, bark, seed, &c. In his day the constitution of water was not known, and there was nothing absurd in his conclusions. But now we know that they were altogether incorrect; for water, when pure, only contains oxygen and hydrogen, and the willow contains, besides these elements, carbon, nitrogen, phosphorus, and several others. Van Helmont was deceived, because he used *impure* water that accidentally contained these other ingredients.

The presence of soil, however, was so evidently necessary for vegetation, and crops grew so much better upon some soils than others, that it became impossible not to believe that the earth in which plants grew had something to do with their structure. Tull, at the beginning of the last century, made a very near approach to the discovery of the truth. He came to the conclusion that the food of plants consisted of water along with earth, and that this water and earth was converted into their structure, and constituted the material bulk to which they attained. The actual chemical constitution of the soil was quite unknown in Tull's time, and he not unnaturally assumed that the earth was taken in by the roots of a plant only when in a state of fine powder, and he inferred that fertility in a soil depended upon obtaining this state of comminution, and that a soil could be rendered and made to remain fertile by continually reducing it by mechanical means to a powder. He tried the theory experimentally upon his own farm. From a peculiarity in his soil his plan succeeded at first, but very soon his land became sterile, and he was ruined. Both earth and water were clearly necessary for plants, but not exactly in the manner that Tull thought. Nevertheless, he was so near the truth, that the practical mode of tilling the soil that he introduced, deep ploughing and drill husbandry, are still regarded as indispensable to all good farming.

Two of the ancient elements had been supposed to furnish the food of plants, and then Waller, or Wallerius, professor of mineralogy at Upsala, about a century ago, in his "Elements of Physical and Chemical Agriculture," maintained that the atmosphere was the main source of the food of plants, and that the air contained all the materials and constituent principles of vegetables; and, which is a most remarkable circumstance, he ascribes, as one cause of the nutritive property of the air, the presence in it of *volatile alkalies* in a state of vapour.

This same Wallerius nearly stumbled upon a still more important discovery. He investigated the action of mineral matters upon plants; but unluckily came to the conclusion that mineral matter was not essential to the structure of plants, and were as unsuitable for food to them as to animals,—"Ils sont aussi peu propres à les faire vivre qu'à faire vivre les animaux."

In England, however, it has long been the custom of the farmers to use mineral manure. This plan is as old as the time of Queen Elizabeth, inasmuch as it is noticed by Camden; and for a long time gaulting, marling, and liming have been practised. Saussure, towards the end of the last century, had clearly demonstrated that plants essentially contained various mineral matters, which differed in different plants. But it was an Englishman, Mr. Grisenthwaite, of Nottingham, who first clearly perceived the relation between the mineral matter of the soil and that of plants which grew upon it. He first published his discovery in 1818, and still more fully in 1830. As the admirers of Liebig have claimed for that distinguished chemist the discovery, it is proper to quote some of the passages from Mr. Grisenthwaite's "New Theory of Agriculture."* "Let us recur once more to the grain of wheat. In that grain there always exists, as has been stated, a portion of phosphate of lime. It is the constancy of its presence that proves beyond all reasonable doubt that it answers some important purpose in the economy of the seed. It is never found in the straw of the plant, it does not exist in barley, or oats, or peas, although grown upon the same ground and under the same circumstances; but, as has just been observed, *always* in wheat. Now, to regard this unvarying discrimination as accidental, or to consider it useless, is to set at defiance the soundest principles of reasoning that philosophy ever bruited. If phosphate of lime had sometimes only been found in wheat, or if it had been discovered in barley or clover, then we might have concluded that the whole was accidental, that it in no way whatever assisted the formation of the perfect grain, nor contributed to promote the general design of it. * * * Agriculture may be considered a system of operations designed to convert manure into certain vegetable matters, and the land or soil performs the office of an instrument in the process. * * * It is only within the last few years that the elements of bodies have been discovered. Before that time the nature of compounds was but little understood, and the transmutation of matter, if not openly acknowledged, was only tacitly denied. The sun of chemistry has at length risen above our horizon, and dispersed much of the darkness of ignorance which covered former ages, and shed an illuminating ray over the various phenomena of nature. Elements, as the very term implies, are now known to be incapable of being changed into each other. They admit, when considered *per se*, of no alteration, but as regards magnitude and figure; and all the variety of matter discoverable in the world is produced by the combination of these elements in different proportions. From this fact we are led to deduce the following important conclusion,—that when out of one substance another is to be formed, as alcohol or acetic acid, by fermentation out of sugar, or, to confine our views to agriculture, grain out of manure, it is obvious that the elements of the first must be contained in the second, as if they be not that conversion cannot possibly take place. This is a truth which applies with peculiar force to the doctrine of manures, and renders it imperatively necessary on the agriculturist to investigate the constituents both of the crops he grows and of the manures he employs to make that crop successful. It is very reasonably *to* be feared that many failures quite inexplicable to the farmer may be explained upon these principles. He has very frequently, perhaps, sown grain upon land which has not contained the elements necessary to the production of the crop, and therefore the crop has failed, and he continues to suffer a recurrence of the same loss year after year, because he is unacquainted with the causes upon which it depends. If all crops were composed of the same elements, this reasoning, this discrimination among manures, would not apply, nor be necessary to be regarded by the agriculturist; and it is upon such a supposition that the practices of husbandry have been uniformly conducted, and are at the present day conducted, with disadvantage."

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* Second edition, published in 1830.

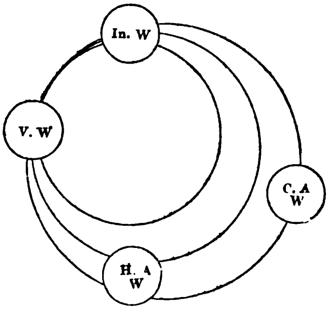
The presence of ammonia in the air, the result of putrefaction, and its forming a source of the food of plants, as suggested by Wallerius, seems to have excited little attention; and, indeed, the beautiful and unquestionably correct theory of Mr. Grisenthwaite was almost equally neglected. In 1840 Baron Liebig published his celebrated work on the connection between chemistry and agriculture. In it he maintained, with Grisenthwaite, the presence of mineral matter in plants, which must be derived from the soil (either naturally present in it, or artificially added in the form of manure), and with Wallerius the presence of ammonia in the air, which, when washed down by rain, furnished nitrogen to the growing vegetable. But he farther maintained, and in this consisted his originality, that the ammonia of the air was the *only* source of nitrogen to plants, and that the roots of plants could obtain none by appropriating and decomposing *nitrates* in the soil. The views of Liebig met with the reception that those of so distinguished a chemist deserved. It was very generally believed that if mineral matters such as composed the structure of a crop, save its nitrogen, were added in a soluble state to the land, the mineral matters would be converted into vegetable matter, and that the crop would obtain its nitrogen from the air. Such mineral manures were manufactured and tried, and the result was a failure. This result was prejudicial to the progress of scientific agriculture; for the farmers, who had imperfectly understood and unwillingly believed Mr. Grisenthwaite's doctrines, appealed to the failure of Liebig's manures as a test of their untruth. But it is now known that plants obtain nitrogen both from nitrates and, in some cases, directly from the atmosphere; and if ammonia or nitrates be added to the other mineral matters, the artificial manure so prepared is no longer a failure, but the cause of luxuriant vegetation.

That increased fertility follows the application of nitrates, particularly to grass, is now a matter of practical notoriety. And that it is the nitric acid and not the base is unquestionable; for while a part of a grass field top-dressed with nitrate of soda will show greatly increased vegetation, another part of the same field upon which common salt is spread will not have its growth in the least augmented. It is also probable too, that the soil is replenished with nitrogen in the form of a nitrate, which has been obtained by the oxidation of the nitrogen of the air, catalytically, owing to the presence of decomposing animal matter. And it is probable that the practice followed in many parts of England of spreading the contents of the manure heap upon grass, so far from being a wasteful, is really an economical process. Very likely, too, the imitation of this custom would cure land that is clover-sick.

To any one who has read the preceding part of this work these remarks will not be necessary to impress the fact, that an appreciation and knowledge of the laws of the Phasis of Matter are the very foundation of all rational farming. Every crop that is or may be grown consists of a congeries of elements aggregated together in uniform proportions, and obtained from the soil and the air. And when any crop is taken from a field, these elements are bodily taken away, and can only be re-accumulated in its soil, either by the decomposition of the subsoil, or the addition of manure or both.

As the food of plants, different in every different species (at least different in the proportion) is derived from the mineral world, which is so arranged in their interior as to constitute their structure; so also the food of animals is derived from plants, and the digestive organs of animals have the power of so arranging the elements contained in plants as to form their blood, muscle, &c. And as all animals are continually returning to the mineral world, either when alive by their excretions, or when dead by the putrefaction of their whole body, we have a very good instance of the Phasis of Matter as bearing most influentially upon rural economy. As seen in *fig.* 132. the vegetable world derives its oxygen from the inorganic. Part of it is seen to die, lose its properties and characteristics, and return to the inorganic world, while another portion of it is eaten by herbivorous animals, and converted into their structure. Some of these herbivorous animals die, become rotten, and merge into the inorganic world; while others of them are consumed by carnivorous animals, which in their turn lose their vital properties, and return to the soil. In all these cases the dead animals or plants have their elements arranged so as to form soluble salts of soda, potassa, iron, &c.; while their carbon becomes converted into carbonic acid and humus, which latter gradually becomes aprocrenic acid, and their nitrogen becomes placed in the form of ammonia and nitric acid.

Fig. 132.



The business of the farmer, then, as far as regards the production of crops, consists in knowing what elements any given crop will require, and in taking care that a due supply of these elements in a mineral state, and also in such alliances as are souble in water, be present in the soil; and, as far as regards the rearing and fattening of stock, that such have a properly admixed quantity of saccharine, oleaginous, and aluminous proximate principles that have been formed by the vitality of plants out of the aforesaid minerals. Besides indeed the administration of a due supply of food, other conditions are necessary. A certain amount of heat in particular is necessary for both vegetable and animal life; and, as we have before had occasion to notice, if the temperature of animals in particular be not well kept up, the saccharine and oleaginous food that they consume is, instead of being converted into fat, used up as fuel and wasted.

We can now understand well enough the *rationale* of the various processes that are empirically followed in farming.

One of the most important rules of husbandry, said Cato, nearly two thousand years ago, was "bene arare," and good ploughing is still essential to the profitable cultivation of the soil. And the action of ordinary ploughing is, that it exposes the elements forming the soil, and particularly the humus, to air and moisture, by the action of which, as before explained, they form combinations that are soluble in water. Grubbing and subsoil ploughing break up a certain portion of the subsoil and add it to the regular soil. Farm yard manure is efficacious just because it restores to the soil those very elements that were previously abstracted from it by the husbandman. The increased fertility of land upon which guano is spread is owing to the guano containing all the elements which ordinary crops require, with the exception of potassa. Bone dust is useful, because it gives to the land phosphate of lime; nitrate of soda, because it gives nitrogen and soda; sulphate of ammonia, because it gives sulphur and nitrogen; and an analogous explanation is to be given of the action of most other manures. Lime likewise acts by combining with the geic acid group of compounds, and also by its abstracting the water of undecomposed vegetable matter, and thereby promoting its putrefaction; and charcoal, from the power it possesses of absorbing ammoniacal and other vapours. Then soil, to be moderately fertile, must contain alumina, because, as before mentioned, that earth has the power of combining with organic substances, and thus prevent them from being washed away. Farther, one action of draining is to prevent evaporation of water, and thereby to increase the temperature of the soil and give increased heat to a crop; and a similar result is obtained in the case of animals, by sheds, houses, hammocks, boxes, &c. Lastly, we may cite the custom that still in places prevails of fallowing land, and which consists in allowing the soil to slowly obtain a new supply of chemical elements from the air, the disintegration of the subsoil, and the conversion of its humus and animal matter into carbonic acid, apocrenic acid, and ammonia.

We can also understand how the geology of a country so affects its agriculture. In these islands we do not possess any very extensive tracts of sands which, owing to their containing little or no alumina allow the organic matter to pass away, and are scarcely worth cultivating; but we have some instances of such. The graywacke does not in general contain much lime, and the lime beds that are found in it cannot, in the existing state of locomotion, be burned, from the expense of conveying fuel. The result is, that arable culture on an extensive scale is impossible upon them, and they are, of necessity, sheep walks. The disintegration of granite and metamorphic rocks naturally tends to produce a fertile soil; but, owing to the steepness of the hills that prevail in such formations, most of the soil that is formed is washed down into the valleys, and much even of this is swept by the inundation of swollen mountain torrents into the sea.

Considering that the farmer who grows the ordinary crops of this country, which require more than twelve elements, it may be inferred that he would be equally liable to allow his soil to get deficient in any of them. But, practically, his difficulty consists in keeping up his supply of nitrogen, phosphorus, and potassa. He can contrive to make up for his great expenditure of the first by means of guano, nitrates, ammonia, and by catalytically obtaining nitrogen from the air. Besides gradually obtaining phosphorus from the subsoil, he also gets a supply from guano, bones, and coprolites. But the great difficulty in very high farming is to keep the soil rich in potassa salts, and the discovery of a cheap source of that alkali would be the greatest boon that could be conferred upon the farmer.

It is plain that many of the practical and empirical rules held in esteem by the majority of the agricultural world are not compatible with the views of science. Taking, for example, two white crops in succession, or in any manner rapidly exhausting the soil, is held to be bad farming, and such practices are usually prohibited in leases. Now, the business of the farmer is just to exhaust the soil, and the more rapidly and thoroughly he does it the more food is produced, and he the better understands his trade. Formerly, when the action of the soil upon the crop was not understood, and when some occult power was attributed to it which required repose, or when plants were supposed to give forth excretions poisonous to plants of their own species, such prohibitions might be tolerated. But now that the action of the soil upon the plant is known, it would appear that prohibitions of cropping and compulsory rotations of crops are improper. It is not taking too much out of the land that is to be avoided, but it is the putting plenty in that must be insisted upon, and if a farmer wishes he may grow wheat every year upon the same field as easily as he eats his dinner every day from the same plate. Formerly, when his only supply of manure was from his own farmyard, he could not; but now, if, as is nearly the case, his supply of food for plants is unbounded, he may grow what he likes and as often as he likes.

The science of the Phasis of Matter is also able to throw great light upon the rational feeding of growing and fattening animals. All animals require a certain amount of either animal or vegetable food rich in carbon, to be used as fuel in the functions connected with respiration. If this amount be insufficient in quantity, the animal first consumes a portion of the carbon of its own fat, and if the necessary supply be still withheld eventually dies. Then every animal daily excretes a portion of every element contained in its structure. To compensate for this loss it must have as regular a supply of these elements from without, in the shape of albuminous articles of food. Farther, the growing animal must not only have a supply of albunimous articles of food to compensate its waste, but also one to afford it the daily increase of bulk that it attains. The fattening animal must in like manner receive a quantity of carboniferous matter greater than it needs for fuel, and which it may store up in its structure as fat. Lastly, the milk-giving animal must have carboniferous matter for its respiration, albuminous matters to make up for its excretions, and also additional saccharine, oleaginous, and albuminous proximate principles, out of which to form the milk.

Besides producing vegetable food and butcher meat, an important branch of farming consists in the manufacture of dairy products. Modern chemistry gives a satisfactory account of the processes carried on in the dairy. Thus, "Milk consists of sugar, caseine, salts, globules of fat (butter), and water. It often, in addition, contains some aromatic principle, derived from the food of the cow.

"After the milk is drawn from the cow, the vital affinities which kept the carbon, oxygen, and hydrogen so combined as to form sugar, cease, and the sugar is gradually converted into another compound of these elements, called lactic acid. In popular language this is called the souring of the milk.

"The fat or butter is in globules mixed with the water of the milk. These globules, when the milk is at rest, gradually ascend to the surface, taking with them a little casein, water, and sugar, or lactic acid. This compound can be skimmed from the surface, and is known by the appellation cream.

"If this cream be heated, the globules of fat burst and unite together. Being lighter than the other constituents of the cream, they ascend to the surface, forming an oily fluid. This may be taken off; and if put into a cool place it solidifies, and is in fact pure *butter*. Butter so obtained will keep a long time without becoming rancid; but it has not the taste of the butter of the shops, and is not used as an article of diet.

"To obtain butter for food, we apply heat, the source of which is mechanical agitation. The cream is put into a churn, the flappers of which are made rapidly to revolve. When by this procedure the temperature is raised from 4° to 10°, the globules burst and adhere together. Butter so procured, besides pure fat, contains sugar, a little casein, and any aromatic principle the cream may possess, and is more suited to our tastes than the pure butter obtained by the direct application of heat.

"Butter made in this manner will not keep fresh long. The sugar is converted into lactic acid; and butter in which this change has taken place is said to have become rancid. If an excess of sugar be artificially added, then this change does not take place. Common salt and saltpetre have likewise the power of retarding this change. In practice it is usual to add a mixture of these three substances—sugar, salt, and saltpetre—to butter which it is desired to preserve for any length of time.

"Casein may be obtained in a tolerably pure state by adding any acid to new milk, skim-milk, or butter-milk. When this is done, the casein, or curd, as it is commonly called, falls to the bottom. The most remarkable property of casein is, that it is soluble in a weak solution of potash or soda; that is to say, that it forms a compound with them which is soluble in water.

"New milk contains carbonate of soda. In fresh-drawn milk the casein is combined with this, and is, therefore, soluble in, and held in solution by, the water of the milk. But as the sugar of the milk is gradually converted into lactic acid, the lactic acid combines with the soda, forming lactate of soda, and the casein, now insoluble in water, falls to the bottom in lumps, filled with water.

"When it is desired, however, to obtain this casein artificially, it is not usual to wait until the lactic acid is naturally formed, but some acid is added. The one commonly employed, at least in this country, is the muriatic acid as contained in the dried stomach of the calf. When this is added to milk, the casein falls to the bottom. It is taken out of the fluid, subjected to strong pressure to squeeze out the water, which it has mixed up with it, and salted. It is now called cheese." *

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* Agricultural Physiology.

No. II.

ARTIFICIAL WARMING.

The means that we employ to heat the air of our houses and other edifices is always by causing some substance rich in carbon make that carbon combine with oxygen. The fuel that we thus employ is almost invariably derived from the vegetable world, as is either recently cut-down wood, or wood that has been grown in the present state of things, and converted into peat, or the fossil wood of previous geological formations, *i. e.* as we commonly call it, coal. The product of the combustion of any of these is to give out carbonic acid into the atmosphere, which carbonic acid becomes the food of future generations of trees, of future beds of peat, and of future deposits of coal. So regularly does the Phasis of Matter take place from living vegetation to fuel, and from combustion to living vegetation again, that it is likely enough that the shell-fish that inhabited the world during the deposition of the carboniferous system, yielded out its carbonic acid to the plant that we are now consuming as coal, and that the breath of William the Conquerer is perhaps now part of a bush in the New Forest.

In considering the subject of artificial warming, two things must be taken into account,—the manner in which the heat produced by the combination of the carbon and oxygen is communicated to the air, and the manner in which the air in which the process is going on is kept purified.

With regard to the former of these, national habits and predilections make us prefer to see the combustion take place, and to have what is called an open fireplace. And as this necessarily supposes a chimney through which a certain amount of ventilation can take place, this has its advantages. There is no doubt, however, but that in general an open fireplace wastes a great deal of the heat produced both by conduction to the fireplace and walls about it, and also by allowing a great part of the heated air to escape up the chimney.

In the fireplace upon the hearth indeed, and in the common old-fashioned open fireplace, it is probable that the whole of the heated air went up the chimney, and that the whole of the heat communicated to the apartment was by means of radiation. And in fact, the whole of the heat that was or might have been radiated, was not so radiated to the air of the apartment, but a great portion was conducted to the fireplace. Count Rumford estimated that, of out of every fifteen pounds of fuel burned in an old-fashioned open fireplace, as many as fourteen are absolutely wasted as far as regards warming the room. His improvement consisted in introducing the register stoves as they are called, in which the entrance to the chimney is very much narrowed. Owing to the rapidity of the draught in them, it was found that the room was warmed with a smaller fireplace and a less expenditure of coals, and that there was far less tendency to smoke. The greatest improvement of all, however, in open fireplaces, is the Kinnaird grate, which is a register, the whole of the back and sides of which are made of fire-bricks, which, when heated, radiate an immense amount of heat. For economy of fuel and intensity of heat, they are by far the best of the grates, and are not open to the objections that apply to stoves.

On the continent close stoves have been for long the common mode of warming apartments. A common form of these is a cylinder of iron, at the bottom of which there is a grating for the fuel, underneath which is an ash-pit. There are but three openings to the stove, one from the ash-pit to the furnace, one from the furnace to a chimney, and one, that can be closed, through which fuel can be introduced. Of course, when the fuel-door is close, and the ash aperture opened, the cold air can only enter by the ash-hole, and the smoke can only escape by the chimney. When the fire is kindled, the iron of the stove soon becomes very hot, and communicates its heat to the warmth of the room. No fuel is wasted, and, of course, smoke is impossible. The draught, too, is so great, that all the carbonic acid produced by the combustion is carried away through the chimney. But, unless measures are provided for ventilation, the carbonic acid of respiration accumulates in the apartment, and, moreover, the heat in the immediate vicinity of the stove is so great, as to decompose the accidental impurities of the air, and give it a very disagreeable odour, which is apt to induce violent headaches. Accordingly the continental close stove has never become popular in this country, and is never seen in apartments of dwelling-houses.

In order to obviate one of the greatest defects of the close stove, its decomposing matters in the air, Dr. Arnott invented his celebrated stove. It essentially consists of a large case of iron, in which is a small fire-box or close stove, and in this manner a considerable extent of surface is obtained which does not attain a heat of more than 200°, and which therefore does not decompose the matters floating in the air. Moreover, the economy of fuel in the Arnott stove is very great. But the great practical objection to it is, that the carbonic acid formed by the combustion inside the stove is very apt to fall down through the ash-pit and so poison the atmosphere of the room.

Almost all the stoves that are advertised are adaptations of either the close stove or the Arnott. Of late an ingenious little stove has been made. Its interior consists of a small fireplace made of bars of iron upon which a gas jet impinges. The heated gas soon makes the iron bars red-hot, and the door of the stove is made of talc, which allows the blaze to be seen. As yet, however, this gas-stove is little more than a toy.

Large apartments, as churches, manufactories, and the like, are often warmed by having heated air brought to them from a stove, or by means of hot water or steam-pipes; but the arrangements for these belongs to mechanics and not to chemistry.

The chemical part of ventilation, too, is soon disposed of. Every time a person performs the act of expiration he drives into the air a quantity of carbonic acid; and also a candle or lamp, as long as it is burning, gives out this same poisonous gas. Although carbonic acid is heavier than common air, yet, owing to the higher temperature of the gas that is cast out by expiration and to ammoniacal vapour being mixed with it, it tends to rise. The art of ventilation, then, consists in having an aperture high up in the room where foul air may escape, and another lower down where pure can enter at.

No. III.

SOAP MAKING.

It was stated in a previous page that the oleaginous principles (or oils and fats), animal and vegetable, resembled in their chemical nature salts, and that they consisted of an acid, the stearic or oleic, combined with a base called the oxide of glycerine. If to these stearates or oleates of oxide of glycerine a a stronger base, as potassa, soda, or oxide of lead, be added, decomposition takes place; stearate or oleate of potassa, soda, or lead is formed, and oxide of glycerine is set free. To the mixture of the stearate and oleate of potassa, soda and lead, and the free oxide of glycerine, the name of soap is given. We need here only consider the composition and manufacture of potassa and soda soaps, for the lead soap is only of interest to the apothecary, and is, indeed, generally styled not a soap but a plaster.

These potassa and soda soaps are, as is matter of notoriety, of great economical value in washing. The cleaning power of soap is owing to two properties that it possesses. First, it can dissolve fat and oils: secondly, when, as is practically done in washing, it is dissolved in a considerable quantity of water, it is resolved into an acid salt and a free alkali, and the latter of these dissolves almost all organic substances, and, therefore, almost all dirt and soils, and the acid salt, by its lubricity, favours the washing away of these dirt solutions.

The soaps may be arranged into two great classes, the hard or soda soaps, and the soft or potassa soaps.

Soda or Hard Soaps.

The oil for making these soaps is in this country usually tallow (sometimes kitchen refuse), but in southern countries the commonest kind of olive oil is often employed. Here from about twelve hundredweights of tallow a ton of soap is obtained. To this a weak solution (technically called a ley) of barilla, or some salts of soda that have been treated with lime so as to obtain caustic soda, is added, and heat is applied for about four hours; during which time the stearate, &c., of soda are formed. The mass is cooled, and a quantity of saline solution drawn off. The whole of the tallow, however, is not yet decomposed, and the process requires to be repeated several times. It is evident, that if the quantity of oxide of glycerine that existed in the tallow were accurately known, the manufacturer might put as much alkali to it as would take its place, and no more; but as in practice he is guided by empirical rules, he puts in a great excess, and thus wastes, according to a sufficient authority, fifty per cent. of his alkali.

Soap made with potassa retains a quantity of water, and is not, like soda soap, a dry soap. In common language such is termed soft soap; and as it is more soluble in water, and its alkali more capable of dissolving organic matter, it is preferred in many manufacturing processes, as, for example, in scouring woollen goods. The fat employed in making soft soap is usually a mixture of tallow with whale and other oils.

Resin contains an acid that can combine with alkalies in a similar manner to that in which the stearic and margaric acids do, and like them it forms a soap; and the common yellow soap of our shops is, in fact, a mixture of fat, soap, and resin, or colophony soap.

No. IV.

ARTIFICIAL ILLUMINATION.

Artificial illumination consists in exposing a substance rich in carbon and hydrogen to destructive distillation, and in igniting the carburetted hydrogen thereby produced. When oil, fat, or wax is used for the purpose, the fat or wax is melted; and these, as is also the case with oil, are made to ascend by means of capillary attraction, through the tubes of a wick (generally an aggregation of cotton threads), at the extremity of which sufficient heat is applied to cause the formation and ignition of carburetted hydrogen. When the wick is enclosed in the centre of solid fat or wax we have a candle, and when it it is suspended in fluid oil, a lamp. Sometimes, however, the carburetted hydrogen is obtained from the distillation of oil, and not consumed at the time, but stored up for future use; and this is still more frequently the case with regard to the carburetted hydrogen obtained from the destructive distillation of coal. Candles, lamps, oil, and coal gas only fall to be very briefly noticed here; but still it is proper to consider each shortly.

Candles are most usually made of tallow: a superior kind is made of bleached wax, spermaceti, or a mixture of wax and tallow. Of late years the stearine of the tallow has been separated and employed alone for the purpose, and so also has the stearine of oil of cocoa-nuts. Candles are always made cylindrical, with the wick in the centre.

It is of great importance, in making candles, to preserve a due proportion between the wick and the quantity of fat or wax. If the wick be too little, then the whole of the melted tallow cannot be absorbed and conveyed up the wick fast enough, and the consequence is, that the superabundant melted tallow runs down the sides and is wasted. If, on the other hand, the wick be too large, the whole of the melted tallow that passes up the wick cannot be converted into gas, and a portion of it passes away as soot; and, moreover, a portion of the wick will be of a black colour and obscure the light. It is owing to the much higher temperature at which wax melts than tallow does, that the wick of the wax candle is made so much smaller; and it is attributable to the same circumstance, that wax candles burn so much longer and with a steadier light. In consequence also of the small wick of a wax candle, whenever the top of it gets charred, it falls out of the perpendicular and thus comes into contact with the air and is consumed; whereas, the charred top of a tallow-candle wick is too bulky to fall from the perpendicular, and requires to be snuffed from time to time. There are, however, ingenious mechanical contrivances now much used to cause the wick to be consumed.

In lamps there is a reservoir for the oil, into which the wick dips. We have previously had occasion to notice the Argand lamp, the blowpipe lamp, and the safety lamp.

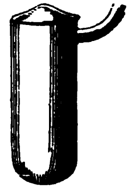
The existence of an inflammable coal gas has been known for upwards of two centuries. Nearly so long ago as the middle of the seventeenth century Dr. Clayton prepared some, which he collected in a bladder and amused his friends by pricking holes in it and lighting the gas that thus escaped. More than a hundred years ago a quantity of it spontaneously escaped from a coal-pit in Cumberland, some of which was collected by the inhabitants, preserved in pipes, and burned at their leisure. It was not, however, until 1792 that coal gas was first made, in order to afford artificial illumination; and this was done by Mr. Murdoch, who erected a small gasometer, and lighted up his own house. The use of coal gas has since then become very extended, is used by almost all towns to light the streets, in almost all public institutions, and, now that the proper mode of purifying is known, is gradually spreading very very much into private houses.

Illuminating gas has also been obtained from oil (and resin), and it has the advantage of being purer, of giving a better light, and it may be compressed into small vases, which may be carried about and burned in rooms. One of these that has a capacity of about a quarter of a foot would burn several hours. But as coal is much cheaper, and as the management of coal gas is now well understood, oil gas is now never used. It may be doubted, however, if oil gas might not be very profitably used in districts where coal is dear; and the apparatus for making it is so simple, that it is particularly suited for making gas on a small scale for private houses.

The manufacture of oil gas is a very simple process. All that is needed is a retort, a receiver, and a tube communicating between the two. The receiver is made red-hot and red-hot stones put into it; the oil is cast into this hot receiver and is immediately converted into gas, which passes off into the receiver. The only purification that is necessary is to pass the gas into some cool vessel, where any undecomposed oil that may have been carried along with the gas may fall to the bottom. By a pressure of about twenty atmospheres oil gas is, in part, converted into a fluid.

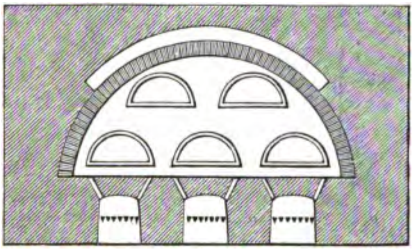
Indeed, the processes for making coal gas and for purifying it are simple enough. The obtaining gas from coal is merely a process of distillation. A quantity of coal is put into a retort, heat is applied, and the gas is given off. The coke that remains behind, although, of course, less in weight just by the quantity of gas given off, is rendered much less compact and more porous, and fills a much larger space. This coke then requires to be extracted from the retort and fresh coal put in; and this extraction of the coke is the only practical difficulty in gas-making. Formerly an iron retort as represented in *fig.* 133. was employed, but it was found very difficult to get the coke out of it. Openings were then made at the bottom, at which it could be raked out; but luting these up was found to be troublesome, and the lute could not be depended upon, and consequently there was always a chance of an escape of gas. This is now accomplished by placing horizontal retorts, in groups of three or more, in a large oven, as represented in *fig.* 134., and the coke is extracted from these by means of long shovels or scoops. Just behind the mouth of the retort a pipe, as seen in *fig.* 135., proceeds, rises perpendicularly, then takes a sudden turn and opens into the main pipe *a*, into which all the other pipes of the retort also enter. The end of the pipe will be seen to dip down into

Fig. 133.



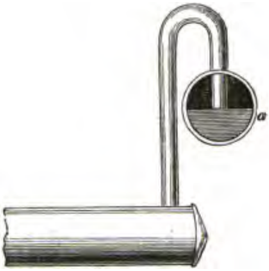
the main tube, so as to prevent the gas regurgitating. Into this main pipe all the gas proceeds, along with a quantity of tar

Fig. 134.



and watery and ammoniacal vapours, which are condensed by the coolness of the main pipe.

Fig. 135.



Besides the water, ammonia, and tar, the gas is mixed with sulphuretted hydrogen, obtained from the destructive distillation of the sulphur and part of the hydrogen of the coal. The two former adulterations are got rid of by forcing the gas through a series of bent tubes, as shown in *fig.* 136., and which are kept cold by means of cold water. As the mixture becomes cooler and cooler, the water and tar become condensed and run out at the orifices *a*, *a*, *a*.

The sulphuretted hydrogen being very poisonous, it is of great importance to get rid of it; and this is now effectually managed by passing the gas over lime. An apparatus as outlined in *fig.* 137. is employed. It consists of three purifiers, A, B, C, each a little lower than the other. A mixture of lime and water is poured into it and gradually passes into B and C. This cream of lime is kept continually stirred by flappers or agitators, seen in each purifier. The gas is forced into it at A, and gradually finds its way out at B. During its passage through the lime the sulphuretted hydrogen and the lime unite together, and form hydrosulphuret of calcium. In order to ascertain that the gas is quite free from this impurity, it is tested with acetate of lead, which it will be remembered is turned brown by sulphuretted hydrogen. If considered sufficiently pure, it is stored in gasometers, and transmitted from them along pipes to its places of destination.

Fig. 136.

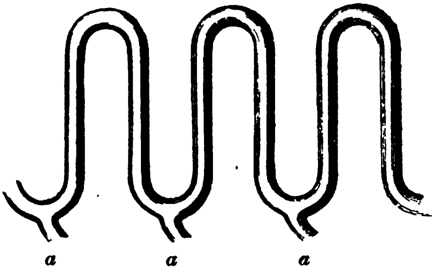
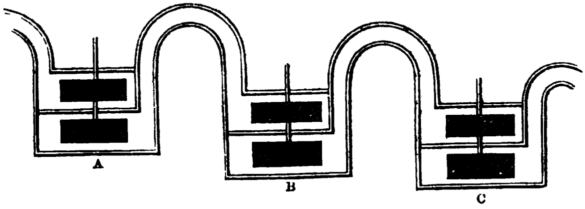


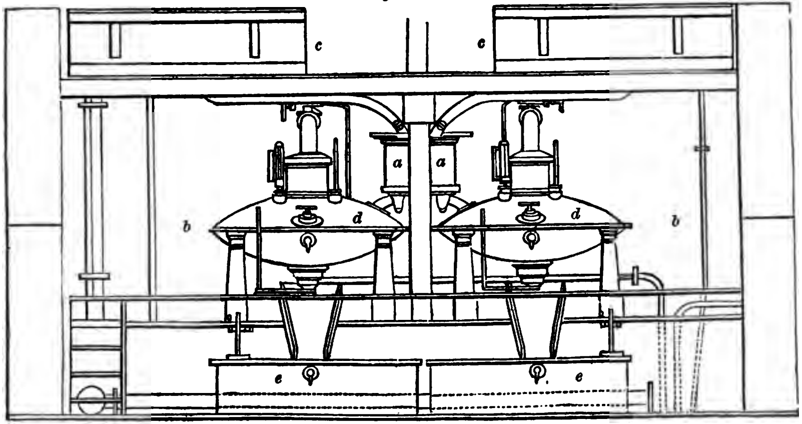
Fig. 137.



According to Dr. Ure, one pound of tallow will make six mould candles that will burn forty hours and cost eight-pence; a gallon of oil capable of affording the light of *fifteen* candles for forty hours costs five shillings, and is therefore half the price of candles. Five hundred cubic inches of coal gas give a light equal to a mould candle for one hour; and when gas is nine shillings the thousand cubic feet, is only one-sixth the price of candles.

The modes of obtaining a light demand a few words. The old-fashioned plan was to strike a piece of iron with flint. Owing to the hardness of the flint a piece of iron was knocked off, and owing to the great friction ignited. The lucifer-matches that have now superseded the tinder-box are composed of a mixture of chlorate of potassa, sulphur, and charcoal, or of sulphuret of antimony made into a paste with gum, and applied to the extremity of a piece of stick previously smeared with sulphur. In the percussion cap the substance employed to send a spark to the gunpowder is fulminate of silver. The apparatus for obtaining a light by the action of hydrogen on spongy platinum and the like are merely philosophical toys.

Fig. 138.



VACUUM PANS, WITH THEIR SUBSIDIARY APPARATUS,

No. V.

SUGAR PRODUCING.

A GREAT many plants contain sugar; but it is here only considered necessary to notice the manufacture and purification of sugar from the cane and the beet-root.

1. CANE SUGAR.

The canes are cut by preference at the time when they are believed to contain most sugar, stripped of their leaves, and taken to the mill, where they are subjected to strong pressure, which drives out their juice. This juice consists of water, sugar, gum, albuminous principles, acids, and salts. When expressed, it is conveyed to a copper cauldron (called the clarifier), where it is mixed with lime and then heated. A quantity of scum, which consists of coagulated albuminous matter, some salts, &c., rises to the top, and the clear liquid is then drawn off, and again boiled, scummed, and evaporated. This process is repeated until a strong solution of impure sugar is obtained, when it is set aside to crystallise. The portion that does so crystallise is then muscovado or raw sugar, and the uncrystallised residue is molasses.

In order to purify the muscovado sugar it is refined. First it is dissolved in water by the aid of steam. The liquid is then heated with some form of albumen which by its coagulation takes up a great many of the impurities, and then filtered through animal charcoal (which decolorises it) into one of Howard's vacuum pans; one of the most important discoveries of modern times, and which produced a very large sum of money to its inventor. The great desideratum was to evaporate the solution of sugar, so as to drive off the water and yet not form any caramel. This is done in Howard's pan by diminishing the atmospheric pressure. *Fig*. 138. represents a view of two vacuum pans with their subsidiary apparatus.

c c are the two cisterns that contain the dissolved sugar; *a a* are the changing measures, supplied by pipes from the cisterns; *d d* are closed pans, from which the air is exhausted; the apparent stop-cock above *b b* is meant to show the handle of the proof sticks, by means of which the consistence of the evaporating liquid is ascertained (this is a mechanical contrivance which hinders the air from entering when a sample is taken out by a proof stick); and, lastly, *e e* are receptacles, into which the sugar is allowed to flow when it is considered sufficiently concentrated. The concentrated solution is then put into moulds, where the solid portions of it assume those forms that we call loaves of sugar.

2. Beet-Root Sugar.

The extraction of sugar from beet-root was very much encouraged by Napoleon I. for, it was thought at the time, political purposes. But an opinion has been gradually growing that the beet would be in this country the cheapest commercial source of sugar, and its production lucrative to the farmer. Mr. Caird in particular has given his very high authority in favour of this opinion. As there is no practical experience of making sugar from beet in this country, the following translated extracts from instructions and information upon the subject by commissioners of the Imperial government may be useful, particularly to any one desiring to try the culture on a small scale.

"The beet-roots, having been well washed and cleaned, must be rasped or grated, in order to reduce them to a pulp. Common white iron rasps will do very well when only a small quantity of roots are operated upon; but if the manufacture is to be conducted on a large scale, a rasping mill, so constructed as to afford in a short time a great quantity of pulp, is necessary.

"The pulp should be expressed in the most rapid manner possible, for fear of its composition undergoing a change.

"The expressed juice should then be placed in earthenware or wooden vessels placed in cool places. After three or four hours more of rest, the liquor must be decanted, and then the evaporation of it commenced. To do this suitably, copper pans are used, which are placed upon a stove that gives as much heat as to keep the liquor always boiling. Some people add to the liquor at this period chalk, or even quicklime; but this addition, which is not always necessary, should be done with great caution, or it may do more harm than good.

"During the evaporation a good deal of scum separates, which must be carefully taken off with a skimmer. When the evaporation has reduced the liquor to three-quarters, it must be allowed to cool a little, and then it must be clarified as follows: —

"Take ten parts of the liquor and one part of the blood of an ox, or any other animal (this blood should be as fresh as possible).* Heat the mixture promptly until it come to the boil. After some minutes, somewhat diminish the temperature, but still so as to keep it, but less actively, upon the boil. A thick scum will soon be seen to rise to the surface of the liquid. When this appears sufficiently formed and coagulated, remove it with a skimmer, and some minutes afterwards filter it by passing it through the flannel or the like.

"The liquor so clarified should without delay be placed in a suitable vessel, where its cooking may be finished, and always kept boiling until reduced to the consistence of a very thick syrup.

"Arrived at this stage, it is cast boiling-hot upon the filtering cloth, and as soon as it is filtered its last evaporation is commenced. To do this, the syrup is put into very shallow and flat vessels, each containing two or three litres or more" (a litre is about the fifth of a gallon). "These vessels are placed in a stove and carelessly covered with pieces of gray paper.

"The heat of the stove should be from 24° to 25° of Reaumur (equivalent to about 72° of Fahrenheit) and exposed to this for several days. Every three or four days it is necessary to ascertain if the syrup is beginning to crystallise, by putting in the finger and moving it upon the edges of the dishes. It is not easy to say precisely what is the time necessary for the crystallisation to completely take place. Sometimes it does so within five, six, seven, or eight days, but sometimes it requires a much longer time; but it rarely, when the syrup is of good quality, is prolonged beyond thirty days at least, unless the keeping up the heat of the stove has been neglected.

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* Any other source of albumen will do as well.

"The syrup is known to be of good quality when, after having been some days in the stove, it does not become thick and viscid, and when its surface presents a pellicle formed by the union of a number of little crystallised points. If it is perceived that the syrup will not crystallise any more, it should be decanted, to let the fluid drain from the crystal; and the decanted syrup may be again placed in the stove, and sometimes it will afford new crystals, but if so, they will be much more impure than the first ones.

"An attempt may be further made to purify the syrup with the intention of obtaining still more crystals of sugar. To effect this, it is diluted with water, and, after being clarified with bullocks' blood evaporated to a proper consistence and then placed in the stove as the first syrup was. In general, however, there is little advantage in so treating the syrup with regard to the sugar that is hoped to be got when the operation is only conducted on the small scale. It is better to reserve this residue syrup, and submit it to fermentation in the manner to be noticed by and by.

"All the sugar obtained by the different processes, being put together, they are put into a cloth and stretched over a frame. The sugar is then sprinkled with a little cold water, which, by entering amongst the crystals, dissolves a portion of the thick syrup that discolours them, and drops little by little beneath the frame. This washing must be repeated, but with the precaution each time of doing it of using only a small quantity of water; that is, only just as much as is absolutely necessary to dissolve out the syrup without also dissolving the crystals.

"These washings being ended, the crystals that rest upon the cloth are far less coloured, but still very far from being pure. In order to render them so, they are kneaded with a little water, and the paste that is thus produced is introduced into a linen bag and submitted to the action of a press. A very moderate amount of pressure, however, must be employed, for fear of rupturing the bag; and if this accident should happen, the pressure must be instantly stopped, and the materials placed in another bag.

"The syrup obtained by this last operation is very thick, very black, and its flavour is most disagreeable. It, along with the product of the above washings, is added to the residue syrup in which the crystals were formed.

"When the pressure is finished, there will be found in the bag a cake of yellow *cassonade*, the flavour of which resembles very much the commercial muscovado sugar of the cane of the same colour. If it is desired to purify it so as to make it into loaf sugar, it must be submitted to the same operations as are practised in refining cane sugar, clarifying, and so forth.

"It was said before, that the syrups which did not afford crystals should be put on one side and reserved for the purpose of being submitted to fermentation. The way to manage this is as follows:— Take what quantity of these syrups that you like, dilute them with water until you bring them to about the consistence of grape must, add to this liquid some yeast dissolved in water, and place the vessel that contains the mixture in a temperature of from 18° to 20° (*i. e.* about 75° Fahrenheit); slightly cover the vase with paper, and soon a fermentation will begin, that will announce itself by the escape of bubbles of gas. A pretty thick scum also forms analogous to that which we see when grape must is fermenting. At the end of some days the agitation and escape of gas diminish. When they have entirely, or nearly entirely ceased, and when the liquor has acquired a vinous odour, it is passed through a hair sieve, and then distillation is proceeded with, using all the plans and precautions employed in distilling wine. By so doing, a spirit of very good quality is obtained, and which may be rendered still more perfect by rectification. This spirit serves all the purposes of brandy.

"The grounds coming from the expression of the scraped beet should also be used. It is quite certain that animals eat them with avidity, and that they contain a large quantity of nutritive matter that promotes fattening."

Such are Mr. Deyeux's very clear instructions for making beet-root sugar on a small scale. The chemical changes that occur in the processes are so very plain, that they require no comment. An outline of the process followed, and the produce obtained on a large scale is also interesting. It is as follows:—

The roots are cleaned, and according to Chaptal — an authority both as a chemist, a farmer, and a manufacturer of sugar—they are better to be well pared with a knife, although by so doing one-sixth is wasted. In this manner six tons of roots are reduced to five. These five are rasped, and reduced to a pulp in a machine made for the purpose, and which does about a ton of roots in the hour. As the pulp is ground, it is put into bags, and the juice, powerfully squeezed out, put into a copper and heated up to a temperature of 178°. When it has attained this temperature, a mixture of lime and water is added, and the heat is brought up to the boiling point. A thick scum comes to the top, and a sediment falls to the bottom. The clear liquid is taken away, inspissated, and then decolorised by means of animal charcoal. The evaporation is continued until a regular syrup is obtained, which is allowed to crystallise. The crystals are purified in the same manner as cane muscovado sugar.

About each hundredweight of beet-root affords about four pounds of good muscovado sugar, and the residuum about nine pints of spirit. The nutritive property of the beet is unimpaired save by the abstraction of the sugar. Assuming that an acre of land produces twenty tons of beet-root, the amount of value obtained would be as follows: —

Sugar, 13 cwts.
Spirit, 400 gallons.
Nutritive matter, equal to about 20 tons of turnips.

Beet may also be converted into beer; and beer made from beet might be sold at a very low rate.

What might be the expense of obtaining sugar and spirits or beer from beet-root in this country would be, if the law would permit it to be done, I do not know.

No. VI.

MALTING, BREWING, AND DISTILLING.

Malting consists in converting the starch of grain (almost invariably barley) into sugar. Brewing (or wine-making) consists in converting sugar into alcohol; and the mixture of alcohol, water, &c., thereby obtained, is called beer or wine. By distillation we obtain the alcohol in a much more concentrated form than in beer or wine. All the three processes are conducted in accordance with well-established scientific principles.

1. Malting.

The saccharine proximate principle of grain is the insoluble (in cold water) starch, and is intended to furnish the young plant with a portion of its food. The end secured by its insolubility is clearly that it may not be washed away. In order, however, that it may afford food to the young plant, it must be converted into some soluble principle; and we saw that when grain becomes exposed to moisture, and a certain amount of temperature, the young germ begins to exercise active functions, and that a substance, diastase, is formed, which converts the insoluble starch into soluble sugar. Malting consists in artificially producing germination, and in killing the young plant when the sugar has been formed, but before the young plant has had time to appropriate it.

The first step in the process is to steep the barley in cold water. As malt in this country is excisable, the law insists that the barley shall be steeped at least forty hours. In warm weather this is too long, and therefore maltsters rarely exercise their trade in summer. The steeped barley gradually absorbs moisture, and swells. At the same time carbonic acid is evolved, and the water also dissolves out a portion of the constituents of the barley. The increase of weight of the steeped barley is on an average ·47 per cent., and the increase of bulk about a fifth. The quantity of carbonic acid evolved is trifling, and the oxygen of it is believed to be derived from the water. The steep water (which has become of a yellow colour) holds from $\frac{1}{80}$ to $\frac{1}{100}$ per cent. of the soluble matter of the barley, and nitrate of soda has been noticed to be invariably present in it. The matter taken up by the steep-water is probably mainly derived from the husk, and the husk may be noticed to become much discoloured by the steeping.

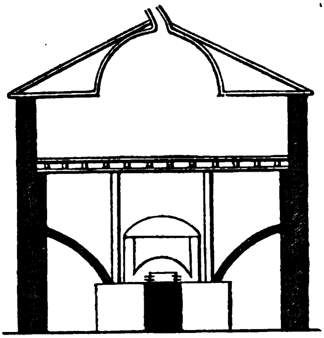
After the forty hours of steeping have elapsed, or longer if the maltster judge it necessary, the water is drawn off, and the moistened barley is put into an enclosure called, technically, a couch, where it is spread to a thickness of about sixteen inches, and where its quantity is carefully gauged by the exciseman. It is allowed to remain here rather more than a day, and is then turned out by means of wooden shovels and spread upon an earthen floor, where it is turned two or three times every day. At each turn, too, it is spread rather thinner. The light is more or less excluded from the room where these turnings are managed; and, in fact, this part of a malt-kiln, in physical properties, very much resembles a soil.

From the time of being put into the couch to its last turning, the changes that take place are interesting; but are exactly analogous to those that occur during germination. First, oxygen is absorbed and combined with carbon, the results being the evolution of carbonic acid and a considerably increased temperature. Indeed, if the barley be not spread continuously thinner, the heat becomes so great, that there is fear of charring. Soon after the increased temperature has been set up, the vitality of the young germ is aroused, and the rootlets begin to strike out. These are three in number; and about twenty-four hours after their appearance the young stem, or acrospire, as it is technically called by maltsters, begins to lengthen. This acrospire arises from the same extremity of the grain as the roots do, but proceeds up inside the husk, and would issue from the opposite end, were not the life of the germ destroyed by means of heat.

During this germination some of the albuminous proximate principles yield diastase, and this remarkable property converts a portion of the starch into sugar.

The germinated barley is spread upon a kiln, as shown in *fig.* 139. The floor is perforated so as to allow heated air to ascend to the malt; and the fuel employed is coke or charcoal, so as to avoid tainting the malt with the vapours of either coal or wood. The temperature is gradually raised up to 140° or more.

Fig. 139.



The whole of the starch is by no means converted into sugar. The following table, copied from Dr. Thompson, shows the changes that actually take place:—

	Barley.	Malt.
Gluten - -	3	1
Sugar - -	4	16
Gum - -	5	14
Starch - -	88	69
	100	100

In the process of brewing, however, immediately to be noticed, it is probable that there is a farther transformation of starch into sugar.

It is evident that in the process of malting there is a portion of the barley lost. So much is carried away by the steep-water; so much carbon is separated in the form of carbonic acid; the matter that enters into the composition of the roots is of course all lost; and there is, from friction, from some of the grains never sprouting, &c., a small waste. The usual loss by weight is as follows:—

By steep water - - -	1·5
By carbonic acid - - -	3·0
Roots - - - - - -	3·0
Waste - - - - - -	·5
	8·0

Moreover, in the kiln drying there is a considerable quantity of water dissipated. The whole diminution in weight from the barley to the malt is usually reckoned at twenty per cent.: but even with all this there is a slight increase of between two and three per cent. in bulk.

The difference between pale and brown or darker-coloured malt is owing to the temperature to which they are exposed in the drying kiln. The darkest kinds of all, indeed, are not fermentable, insomuch as the sugar is all converted into caramel, and these dark kinds are only used to communicate colour.

2. BREWING.

This process essentially consists in converting the starch of malt into sugar, and then in converting this sugar, and also the sugar that already exists in malt, into alcohol. The latter of these changes is effected by the catalytic action of modified gluten or yeast, as it is commonly called; and the former by the diastase. In practice it is necessary not to apply too high a temperature, for fear of converting the starch into dextrine.

The first step in the process is to get a solution of sugar. To do this the malt is ground, and successive quantities of water of a temperature of from 157° to 160° are poured upon it; and the lower temperatures ought to be begun with first. By so acting the sugar is obtained in solution, and then the starch and diastase are procured; and the reason that a higher temperature than 160° is to be avoided, is the fear of converting the starch not into sugar, but into dextrine.

These processes of infusing the malts are technically called mashings, and various mechanical contrivances are arranged in the mash tub which do not here concern us.

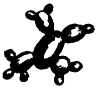
When as much sugar as possible has been obtained by the mashing, the saccharine solution, or wort as it is called, is boiled for a considerable time; three purposes being served by the boiling; 1. The solution is concentrated, a quantity of water being driven off in vapour; 2. A great portion of the albuminous matter is coagulated, and hence the chance of the beer afterwards running on to the acetous fermentation diminished; and, 3. What little starch there is left is converted into dextrine, and a purer solution of sugar obtained.

For a long time past it has been usual to add hops during this boiling process. The common opinion is that they prevent the beer from running on into the acetous fermentation; but this is probably quite without foundation, for beer was made in the country which kept well enough hundreds of years before hops were introduced. The real action of the hops is probably to communicate a bitter and aromatic flavour.

It is found in practice that the best beer is made when the time that elapses between the boiling and the addition of the yeast to excite fermentation is least. The reason of this probably is, that when the period is long, some of the saccharine and albuminous proximate principles begin to react upon one another. The cooling is generally effected by means of evaporation, and for this purpose the boiled wort is spread out into shallow coolers, so as to expose as large a surface as possible to the air. As March and October are the two months during which in general evaporation goes on more rapidly than even in colder weather, March and October-made beer have long been famous.

The reason that the wort must be cooled before the yeast that is intended to act catalytically is added, is that yeast is destroyed by a temperature much above 85°. A temperature of about 60° seems in general to be preferred. The yeast is then mixed with a quantity of wort, and this mixture next carefully stirred among the whole wort. The structure of yeast is seen in *fig.* 140. It consists of little, apparently vegetable, cells filled with albuminous matter taken from previous malt, and which in the process of fermentation throw out new cells that fill themselves with albuminous matter contained in the present malt, and at the same time catalytically resolve the sugar into alcohol and carbonic acid, the latter of which passes off as gas.

Fig. 140.



The fermentation lasts for some days. The greater quantity of the newly formed yeast rises to the surface, and has a very light appearance, owing to its being permeated with globules of carbonic acid gas. Another portion, however, falls to the bottom of the vessel in which the process is conducted. The fermentation is known to be finished by testing the specific gravity of the fluid, and on the small scale by observing that carbonic acid is no longer given off. When this is the case, the yeast is skimmed off, the beer removed from the bottom yeast and any albuminous matter that may still remain among the beer, removed by means of isinglass. The beer is then ready to be barreled.

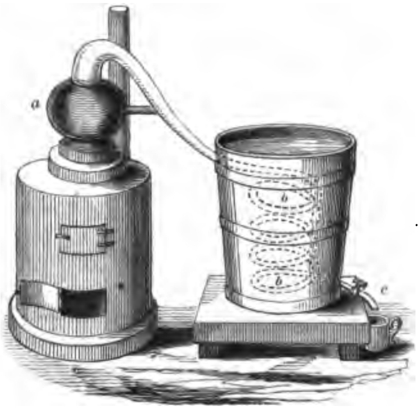
It is obvious that any saccharine matter, or any starchy, if diastase be present, is capable of being converted into beer, as sugar, potatoes, raw grain, or a mixture of any such with malt.

Wine-making in no respect differs in principle from beer making. The sugar is contained in the ripe juice of the grape, and the ferment in the gluten of the skin. The ferment of apple also in cider making is the albuminous principles contained in the apple.

3. Distilling.

Properly speaking, distillation consists in taking advantage of the fact that alcohol vaporises at a lower temperature than water. If, therefore, we take a mixture of alcohol and water, as beer and wine essentially are, apply the proper amount of temperature and no more, the alcohol distils over in a state of vapour and is immediately condensed by cold. The apparatus necessary for the process is a still. One of the old-fashioned kind of these is represented in *fig.* 141. *a* is the copper for

Fig. 141.



holding the fluid from which the alcohol has to be distilled. When to this a moderate amount of heat is applied (alcohol having a specific gravity of ·8519 vaporises at 179°), alcohol, combined with some water and in practice also with other impurities, passes into the worm *b*, which goes round and round in coils in a tub of cold water, and in which the vapours are condensed and run out at *c*. But this distilled fluid always in practice requires to be separated from impurities; and, moreover, in the great majority of cases of distillation in this country, northern Europe, and our West Indian colonies, a pure wine or beer is not taken, but one prepared for the purpose, and which is never used as an ordinarily fermented beer or wine.

Sugar itself is often fermented for the purpose of distilling a spirit from it. In order to obtain the best rum, the juice of the fresh sugar-cane is taken. This consists of water holding in solution fifteen or sixteen per cent. of sugar, some essential oil, albuminous matter, &c. The albuminous matter is quite sufficient to excite catalytically fermentation, and to cause the sugar to be converted into alcohol and carbonic acid. But in practice it is usual to add woollen cloths that have been dipped in the fermenting vats of the preceding year, in order to accelerate the process. When the product of the distillation is distilled, there comes over along with the alcohol the essential oil, to which essential oil rum owes its peculiar odour and taste. Molasses can be made to ferment also; but as they contain no albuminous matter yeast must be added to them, and the spirit distilled from them does not possess the peculiar flavour of the rum, owing to the essential oil having been dissipated in the boilings which they have undergone. In the same manner, if considered advisable, spirit might be distilled from the sugar of beet-root, parsnips, carrots, and many other plants. Occasionally, too, when grain has been very dear in this country, ardent spirits have been obtained directly from sugar that had been imported from the colonies.

The common source of spirit made in this country (usually called whisky, or its liqueur, gin) is grain; and the grain almost universally employed for the purpose is barley. This is ground and mixed with a certain portion of ground malt, and the mixture is mashed as described for brewing. The diastase of the malt converts the starch both of the malt and grain into sugar. To the solution of sugar thus obtained yeast is added, whereupon fermentation takes place, and the alcohol (mixed with impurities) may be obtained by distillation.

In the north of Europe the starch of potatoes is very much employed for the purpose of being converted, first into sugar and then into alcohol; the last of which is separated by distillation. The potatoes are steamed, made into a paste, and malt added to the mass. Fermentation soon begins, which is likewise promoted by the albuminous principles of the potato. When it is finished the spirit is distilled off.

Brandy is the distilled spirit of wine, although that of the apple or of cider is pretty often substituted for it.

The minutiæ that require to be attended to in preparing the above spirits belong more to mechanics than to chemistry. A short notice, however, of the distillation of corn-spirit in this country seems proper.

The principle of the stills still employed is the same as of that figured in *fig.* 141.; but their structure has become much more complex. In a distillery on a large scale there are usually two stills, a larger and a smaller. In the former the beer, technically called the wash, is put, and a spirit, mixed with impurities and a large quantity of water, called by the distillers *low wine*, is distilled off. The smaller still is the low-wine still, in which the low wine is distilled, and a much stronger spirit obtained. During these distillations a quantity of the oleaginous principles of the grain come over, and these have a most disagreeable odour and taste, and are, moreover, very injurious to the health if drank. In order to get rid of these *feints*, as they are called, and which are known by their milky hue, they are carefully separated from the limpid spirit by conducting them, by distinct channels, as they begin to flow from the worm-head, into separate receivers.

A still, however, is now invented by the use of which the whole process may be conducted at one operation. Its details, however, are too complicated to be described here.

No. VII.

LEATHER MANUFACTURE.

The skins of animals are rendered not liable to putrefaction, and also soft and impermeable to water, 1. By tanning, or making the gelatine of them combine with tannic acid, a process to which currying is subservient; 2. By tawing, or combining the gelatine with alumina; and, 3. By shamoying, or the action of fat.

1. Tanning and Currying.

The art of tanning is unquestionably one of the oldest, and one, too, the essential principle of which is known well, although its processes and manipulations have not received much aid from science. This particularly applies to the making of thick leather to be employed for the soles of shoes and such like purposes, that require great solidity. The hide of the animal is taken and steeped for a few days in lime-water. This by its causticity loosens the hair and epidermis; both of which, along with any bits of fat, are then easily removed with a knife constructed for the purpose, the hide being spread upon a hard round bench.

In many tanneries the hide is then immersed in a weak solution of sulphuric acid and water, which has the effect of decomposing a small portion of the cellular tissue near the surface. This makes the surface look more porous, and is held, but surely without any great probability, to facilitate the chemical union of the gelatine with the tannic acid that is going to be applied to it.

The following table exhibits the relative proportion of tannin contained in a hundred parts of the following substances: —

White inner bark of oak	72
Coloured middle bark of do.	19
Entire bark of do.	29
Do. of Leicester willow	33
Sicilian sumach	78
Nutgalls	127
Bengal catechu	231
Bombay do.	261

The substance, or rather the substances, called artificial tannin, has not, to our knowledge, been used in actual practice. Indeed, few of the above-mentioned substances are ever seen in the tan-yard, and the materials actually employed are bruised oak bark (and this by far to the greatest extent of any), catechu, called by the tanners Japan earth, or terra Japonica, and Velonia acorns; the last being the fruit of the *Quercus Ægilops*. When the oak bark is used, the hides are put into a pit with layers of it between them, and then a solution of oak bark (sometimes prepared with hot*, sometimes with cold water) is poured over them. After the expiration of a month or so, they are supposed to have exhausted the strength (*i. e.* the tannin) of the ooze, as the solution of bark is named, and are removed to another pit, where the hides that were at the top in the previous pit are put at the bottom, and where the solution is made stronger. This process is repeated until the whole of the gelatine has combined with the tannin, as is indicated by a section of the hide, made from inside to outside, presenting a uniform brown appearance, any white streak indicating uncombined gelatine. In the case of calf-skins, or those of young cattle (kips), the process is completed in a few months; but, according to the old plan, it takes a twelvemonth or more to thoroughly tan a thick hide of an old animal. When the process is completed, the leather, or tannate of gelatine, is slowly dried, and during the drying compressed in various mechanical manners.

A priori we see no reason why the union of tannin and gelatine should not be made to take place in a few minutes, instead of requiring months, and various plans have been devised to expedite the process of tanning. But a practical objection has hitherto been found to oppose itself to most of these. The tanning took place too rapidly, and a layer of leather was formed outside, which effectually prevented any solution of tannin or ooze getting to the gelatine inside, which therefore remained uncombined. The only plan that has hitherto seemed possible is the patented one of Messrs. Herapath, which consists in first applying a weak solution, and then squeezing most of it out by mechanical pressure, and then applying a stronger solution, and so on. In this manner it is said a strong hide may be tanned in a month or two and good leather be produced.

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* As tannin is soluble in cold water, there does not seem to be any advantage in using hot.

Currying or dressing leather, so as to give it lustre, colour, suppleness, and smoothness, has not much reference to chemistry. The process is usually applied to the thinner skins, and not to those intended for soles and other coarse purposes. First of all, the leather is moistened with water and well beaten with a wooden mallet, and then rendered smooth by being shaved with a peculiar shaped knife and rubbed with pumice stone. It is then rubbed with oil (made by boiling sheep-skins in cod oil), and blackened with a composition of oil and lamp black. For making leather for shoe-tops, this composition is applied on the inner or flesh side; but for other purposes it is blackened on the outer or *grain* side. Horse-hides are sometimes dressed in this manner; and as such leather was formerly much made at Cordova, it is called *cordovan*.

2. TAWING.

This is the mode of converting the skins of sheep, lambs, and kids into soft leather, for the purpose of making gloves and the like. Its theory is soon told. Gelatine is not precipitated by solutions of alumina; but if common salt be likewise added, chloride of aluminum is formed, which is immediately decomposed and a compound of gelatine and alumina, which does not tend to decompose and is tolerably impervious to water, is produced. This is tawed or alum leather. The preparatory process, at least for making leather for gloves, &c. consists in soaking the skins in lime-water, cutting off the fat, &c., in the same manner as in ordinary tanning. They are not soaked in diluted sulphuric acid, but in a mixture of bran and water. The albuminous matter of the bran probably sets up some catalytic putrefactive action that may decompose out some of the skin and render it more porous; but the utility of the proceeding seems very doubtful. They are then put into a solution of sulphate of alumina and potassa, and common salt mixed in empirical and indeed varying proportions.* Into this solution the skins are immersed, and the chemical action between the gelatine and the alum salt is completed in about ten minutes; in this respect forming a remarkable contrast to ordinary tanning. They are then subjected to a modified currying process, First of all, a mixture of wheat flour and yolk of eggs, *i. e.* of albuminous matter, is diligently rubbed into them; and this mixture of albuminous matter is found to keep them soft and enable them to suffer without breaking the pressure of a large iron which is rubbed over them. They are further softened and polished by rubbing with pumice-stone, ironing with hot irons, &c.

When skins are to be tanned with the hair or wool on, no lime is used, as that would make it fall off.

3. CHAMOYING.

Chamoy skins were formerly prepared in this manner to make wash leather, and now those of sheep and goats are likewise used for the purpose. Chamoying can scarcely be called a chemical process at all, since it consists in mechanically expelling as much albuminous matter as possible and filling up its place with oily matter, cod oil being generally used. In this manner putrefaction is prevented and great pliancy obtained.

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* It would appear to be the custom to use more salt in summer than in winter.

No. VIII.

PRESERVATION OF WOOD.

A VERY few words will be sufficient for describing the principles upon which wood may be prevented from rotting. As we have before seen, the lignine tends, when exposed to air and moisture, to become converted into humus, and the change is promoted by the catalytic action of the albuminous principles that are present in wood.

To preserve wood from the dry rot, as it is called, the access of air and moisture is prevented by coating the surface with tar or paint, and the albumen is rendered insoluble by being combined with some deoxidising substance, of which corrosive sublimate is perhaps the best.

No. IX.

MANUFACTURE OF GLASS, POTTERY, ENAMEL, AND ARTIFICIAL JEWELS.

1. Glass.

This substance, on account of its extreme ductility when heated, and its hardness and resistance to almost all acids when cold, affords perhaps as much comfort to man as any chemical compound. It is not indeed a definite chemical compound; for the term glass comprehends a number of compounds of silicic acid (the acid being in excess over the bases) with potassa, soda, magnesia, lime, and oxides of iron, manganese, and lead. The following table exhibits the composition of nine different kinds of glasses that are found in the market:—

	No. 1.	No. 2.	No. 3.	No. 4.	5.	No. 6.	No. 7.	No. 8.	No. 9.
Silicic acid - -	71·7	69·2	62·8	69·2	60·4	53·5	59·2	51·9	42·5
Potassa - -	12·7	15·8	22·1	8·0	3·2	5·5	9·0	13·8	11·7
Soda - - -	2·5	3·0	—	3·0					
Lime - - -	10·3	7·6	12·5	13·0	20·7	29·2	—	—	·5
Magnesia - -	—	2·0	2·6	·6	·6	—	—	—	1·8
Alumina - -	·4	1·2		3·6	10·4	6·0			
Oxide of iron -	·3	·5		1·6	3·8	5·8	·4		
do. manganese	·2	—	—	—	—	—	1·0		
do. lead - -	—	—	—	—	—	—	28·2	33·3	43·5

No. 1. is the hard Bohemian glass used in the laboratory.
No. 2. is common Bohemian glass, much more fusible than No. 1.
No. 3. is English plate glass.
No. 4. is German do.
No. 5. is French glass.
No. 6. is do.
No. 7. is English crystal.
No. 8. is English flint glass.
No. 9. is Guinand's optical glass.

The opaque glass of lamp screens, &c. has oxide of tin mechanically mixed with it; and bottle glass is crown glass with a large proportion of protoxide or peroxide of iron, to which respectively it owes its green or brownish-yellow colour.

The materials used in glass making are:—

1. Quartz sand, to afford the silicic acid.
2. Lime, and sometimes its carbonate.
3. Pearl ashes, to afford the potassa.
4. Carbonate of soda, or sulphate of soda, or chloride of sodium, to furnish the soda.
5. Red oxide of lead, to furnish that metal when it is required.
6. Black oxide of manganese.*

Sometimes, too, for a reason immediately to be mentioned, carbon in some form, nitrate of potassa, and arsenious acid are added to the mixture.

Whatever are the materials fixed upon, they are reduced to fine powder, intimately mixed, and exposed to great heat. The chemical changes that take place are as follows:—The silicic acid combines with the alkalies and earths, the carbonic acid is expelled, and silicates are formed. When sulphate of soda is employed, it is of course necessary to get rid of the sulphuric acid; but in order to effect this some little management is requisite, for silicic acid cannot quite decompose sulphate of soda. If, however, some carbonaceous matter be introduced, carbon combines with some of the oxygen of the acid, and carbonic acid and sulphurous acids are expelled as gases. The iron present tends to go into the form of a protoxide, and when in that state communicates a green hue to the glass. This is prevented by adding nitre or peroxide of manganese, either of which afford oxygen, to it, and convert it into the peroxide. Sometimes arsenious acid is employed for this purpose. As, however, in this case metallic arsenic is evolved, the practice is objectionable. When lead is employed, the silicic acid forms a salt with it.

The number and variety of glass furnaces are very great. *Figs.* 143. and 144. represent a crown-glass smelting and annealing furnace. 1, 2, and 3 are working holes, into which the crucibles are introduced, and also air admitted; 4, 5, 6, and 7 are blowpipe holes for warming the blowpipes; 8, 9, and 10 are holes

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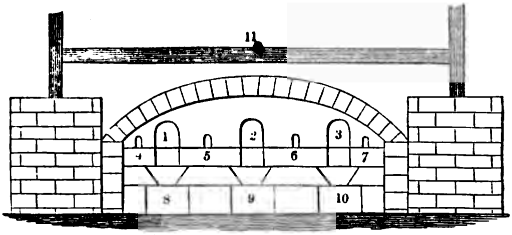
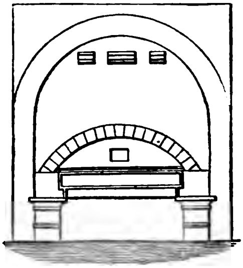
* None of the books that have fallen in my way state where the iron comes from. I suppose it is contained in the potashes. For making coarse glasses instead of potashes the refuse of the soap-boiler is employed.

Fig. 142.



for mending the pots; and 11 is a large bar of iron to keep the furnace together, the fierce heat that is carried on inside of it tending to split it by expansion. The annealing furnace requires no explanation.

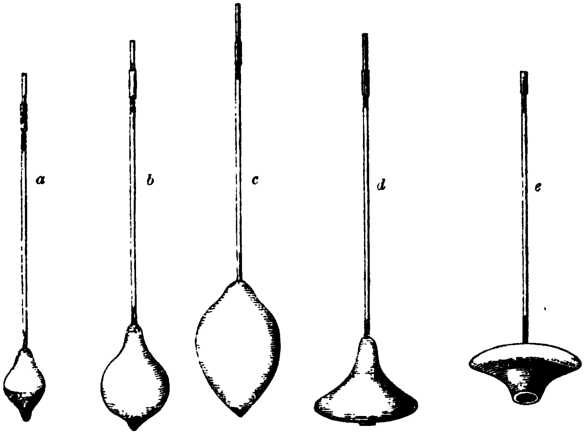
Fig. 143.



The *rationale* of the annealing process is interesting. When a large piece of glass is allowed rapidly to cool, the internal portions do not get time to contract properly, and the result is, that they do not assume a stable arrangement: and when made to vibrate by being scratched, or a bit broken off, their disposition is changed, and the mass explodes and falls to powder. An annealing furnace is a long gallery containing a number of moveable iron trays. The glass is put on one of these and exposed to the greatest heat of the furnace; the tray is then moved to a part not quite so hot, and so on until it reaches at last a part that is quite cold. This regular passage from hot to cold lasts many hours, and the particles of the glass in so cooling assume a stable arrangement.

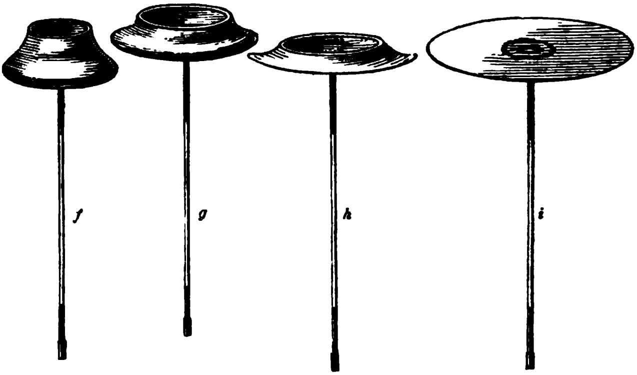
The manner in which glass is made to assume its different forms and shapes belongs to mechanics; but the manner in which sheets of window-glass are made is so curious, that we may notice it. The workman dips his long iron pipe, warmed, in the furnace, as seen in *fig.* 142., into the molten glass, and by dipping it repeatedly gathers as much around it as he judges sufficient for his purpose. This he rolls upon a polished iron table, and blows down the mouthpiece until the glass assumes the appearance of *a*, *fig.* 144. This is again heated and again blown until it takes the form of *b*; again heated and blown twice until it acquires the forms of *c* and *d*. The tube is then drawn out, and another tube stuck in at the other end, as in *e*. The glass is then heated and rapidly turned round; when it opens and gradually assumes the forms *f*, *g*, *h*, *i*, *fig.* 145., until it at last flies open into one immense circular sheet of uniform

Fig. 144.



thickness, save that there is a lump at the place where the tube was attached.

Fig. 145.

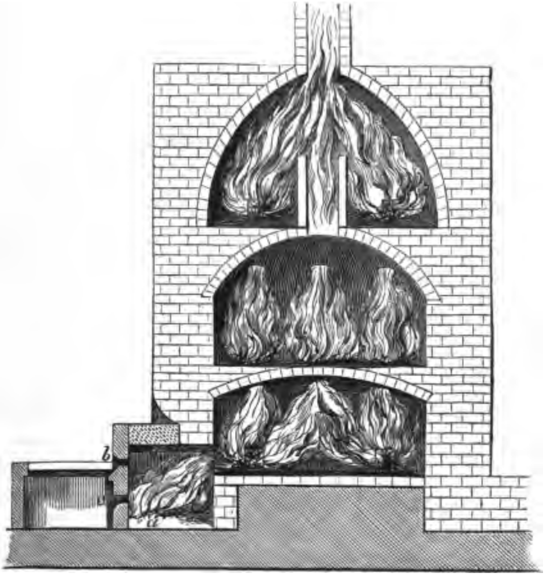


2. PORCELAIN AND EARTHENWARE.

These substances consist of clay from which a quantity of water is expelled by means of heat, and its porous structure then filled up with a fusible glass, which renders it water-tight. Pure clay not being easy to procure, is only used in the manufacture of the very finest kinds of porcelain. In order to obtain it, felspar (a mixture of silicate of potassa and silicate of alumina) is taken, and the silicate of potassa washed out by means of water. For inferior kinds of porcelain clays are employed which contain lime and potassa; and for common earthenware clay containing iron is used, and this is the reason of the red or yellow colour of such articles. In practice, too, silica is added to clay, when china and earthenware are intended to be made; and this, when exposed to heat, combines with the potash, and in fact forms glass.

The moulding into shape of earthenware belongs to mechanics and not to chemistry. When the desired shapes are obtained they are moderately heated, so as to expel some of the water, and then what is technically called *glazed; i. e.* covered with melted glass, which enters into all their pores and coats the surface; and great varieties of glazes are used, the coarsest being common salt, which is thrown upon the red-hot earthenware, upon which water and the chloride of sodium and the silicic acid act upon one another, hydrochloric acid is give off, and the glaze of silicate of soda left behind. The glazes for the finer varieties consist of silicates of alkalies, and oxide of lead, which are made into a glass, ground to powder, and suspended in water, into which the articles to be glazed are repeatedly dipped. When a sufficient quantity of glaze has adhered to the sides, the pottery is exposed to great heat in a porcelain kiln, *fig.* 146. It usually consists of three stories; in the uppermost of which the capsules upon which the articles are placed to be dried; a middle one, where the earthenware is exposed to heat before being glazed; and the lowest, where the final heating takes

Fig. 146.



place. Fuel is placed into *a*, a cavity that is kept supplied with air through the apertures *b* and *c*. The heat is allowed to increase in *a* for six or more hours, until it is full of ignited fuel, and a strong draught set up. The space *a* is then filled with fuel, and all the air that then is allowed access to the kiln passes through it, and thus a great and uniform heat is kept up for seventeen or eighteen hours. The pottery is then allowed to cool slowly for three or four days, and is then, unless it is decided to paint it, complete.

These paintings are produced by staining the glaze with metallic oxides; those of cobalt giving a blue, of iron and manganese a black, and of gold a crimson colour. Chloride of gold and platinum are also dissolved in oil of turpentine, heat applied, and the solvent and chlorine driven off.

3. ENAMELS.

These are varieties of glass, usually rendered opaque or coloured by the addition of metallic oxides and metallic salts. They are used for painting upon, but to a much greater extent for making faces for clocks and watches. They are also used, but to a smaller extent, for making artificial eyes and such like purposes. A great many different kinds of enamels are made, and the details and processes are always kept as secret as possible. The following is an outline of the *principle* of the manufacture:—

Quartz or flints are fused with common salt, to obtain the soda glass or silicate of soda. Oxides of lead and tin are mixed with this, and an opaque and white enamel is obtained, which, if desired, may have various colours and tints communicated to it by mixture of various metallic oxides.

4. ARTIFICIAL JEWELS.

The basis of all artificial jewels is a substance called strass, and which is a metallic glass formed by smelting rock-crystal, white lead, and borax. Sometimes a salt of potassa is employed, and some oxidating agent, as black oxide of manganese or nitre added. This strass by itself constitutes artificial diamond. To form some of the other gems metallic oxides are added. The following are some of the recipes: —

Artificial Sapphire. To twenty-four ounces of strass one hundred and forty-six grains of oxide of cobalt are added.

Artificial Ruby. To sixteen ounces of strass add a mixture of two drachms and forty-eight grains of the precipitate of Cassius, as much peroxide of iron, of golden sulphuret of antimony and of manganese calcined with nitre, and two ounces of rock crystal.

Artificial Emerald. To fifteen ounces of strass add one drachm of carbonate of copper and six grains of glass of antimony.

Artificial Opal. To one ounce of strass add ten grains of horn silver, two grains of calcined magnetic ore, and twenty-six grains of an absorbent earth.

These directions are copied from a French authority.

No. X.

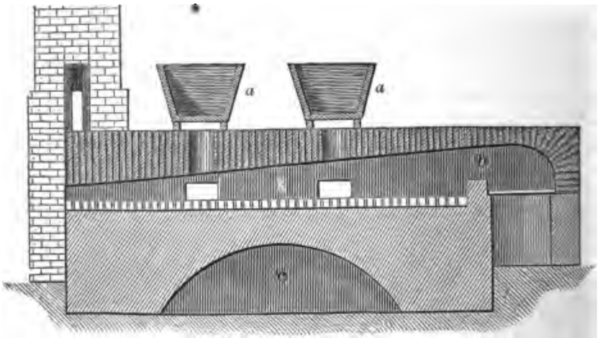
METALLURGY.

The art of separating metals from the substances that they are combined with in metallic ores depends entirely upon chemical principles. The subject is a very extensive one, and all that can be attempted here is to describe some of the more important of the processes followed in this country.

The most abundant of the English copper ores is copper pyrites. It is a double sulphuret of copper and iron, and generally contains also a little arsenic. The processes followed in Wales (where all the copper ore is sent) are as follows:—

1. The ore is introduced into a calcining furnace, such as shown in *fig.* 147. *a a* are two hoppers, into which the ore is put and through which it falls upon the hearth *b*: from this latter

Fig. 147.

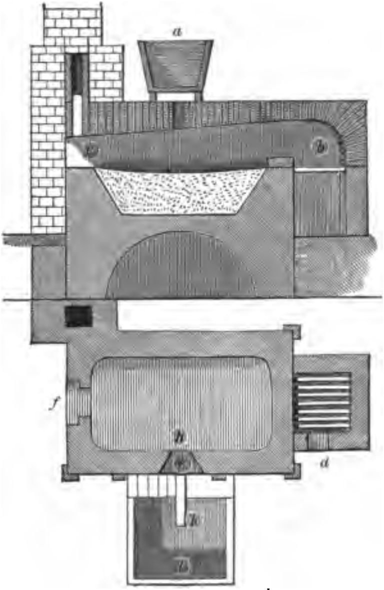


there is an opening, through which the calcined ore can flow into the vault *c*.

Usually about three tons of ore are calcined at a time, and the heat is applied for about twelve hours, and is as intense as the ore will bear without fusing. The result of the operation is, that the elements of the ore are oxidated, the arsenic and sulphur pass off as arsenious and sulphurous acids, and oxides of iron and copper are left behind.

2. The calcined ore is then melted in a melting furnace, such as shown in *fig*. 147. and *fig*. 148.; the former of which exhibits a perpendicular and the latter a horizontal section. *a* is the hopper through which the calcined ore is introduced; *b c* the hearth; *d*, *e*, and *f* are three doors. Above *f* is a hole for allowing the molten metal to escape, from which a tube *h*

Fig. 148.



proceeds and conducts it into a pit, *k*, which is in a larger pit, *l*, filled with water.

In this process a quantity of accidentally present earthy matter is got rid of, and also some of the iron, while the impure copper, by falling into the water, becomes granulated.

3. The granulated copper is then roasted, that is, kept for a long period at a high temperature, and at last melted. During this process, any sulphur that remains is vaporised, and the copper and iron (I suppose owing to the difference of their specific gravities) are separated. The copper, however, is in a state of oxide, and the oxygen is removed by roasting it with charcoal, this process being called refining.

As may be supposed, the evaporation of arsenic in the first part of the process is very injurious to the health of the workmen. In Mr. Vivian's copper works the exhalations are made to pass along galleries, through which showers of water are made to pass; and in this manner great part of the arsenious acid is washed down.

The most important ore of lead is galena, which is a sulphuret of the metal mixed with earthy matter and usually a little silver. The ore is first roasted; during which it acquires oxygen, and the sulphuret of lead becomes converted into the sulphate of the oxide of that metal, and the earthy matter, from its lower specific gravity, floats on the top and is skimmed off. It is next smelted with coal and lime, the former of which removes the oxygen, and the latter the sulphur. The metal is then laded into cast-iron moulds, and constitutes the pig-lead of commerce.

Pig-lead, however, contains silver. This admixture, however, does no harm, and if in very small quantity, is not interfered with. Occasionally, however, there is as much silver present as to make its extraction pay. To separate it advantage is taken of the fact that lead when heated to redness in contact with air easily oxidates, while silver does not. Accordingly, a cupel (a shallow dish of sufficient size) is filled with a mixture of burnt bones and fern ashes, and the lead, or rather alloy, placed upon it, and the whole put into a furnace. When the lead is melted, blasts of air are made to play upon its surface, by means of which the lead is soon converted into oxide or litharge, which is driven to the opposite side of the furnace to that at which the air enters. The silver is then left behind, and then the litharge is deoxidated by heating it with some carbonaceous matter.

Metallic zinc is now much used for lining cisterns, roofing, and the like. Its principal ores are the sulphuret and carbonate. The former is roasted and oxidated, the sulphur being expelled, and then heated with carbon. The carbonates merely require heating with carbonaceous matter.

The most important of all the British metals is unquestionably iron, but the principle of its extraction from its ores has perhaps been sufficiently explained in the body of the work.

No. XI.

DYEING AND BLEACHING.

1. Dyeing.

This consists in combining with cloth or other fabric a substance of another colour than it has, and which produces a compound with some part of the fabric that possesses the desired tint, and is not soluble in water. Hence, dyeing is purely a chemical process, and consists in forming new compounds. Nevertheless, the art of dyeing is pretty much an empirical one; and it would not be easy to definitely state the exact nature of the changes that take place in its various processes. This is partly owing to the imperfect state of our knowledge regarding the composition of many of the colouring matters employed, and partly to the custom, too common in many of our manufactures, of having secrets and secret works. It is only when the arts attain the position of the art of medicine (and to a great extent of that of agriculture), in which it is held disgraceful and discreditable to keep any improvement a secret, that science can to the full extent that she is able increase human comfort and happiness.

The colouring substances employed by the dyer are of two kinds, substantive and adjective. Any substance that can at once combine with the fabric, as, for example, indigo, and form a coloured, insoluble compound with it, is a substantive dye. But few such colours exist, and most of the adjective colours cannot form an insoluble compound with cloth; but a third substance, or a mordant, as it is called, which can form an insoluble coloured compound with *both* the fabric and the colour, requires to be employed. A very common mordant is alumina, which, it will be recollected, has a very strong affinity for organic substances. Compounds of iron and tin are also employed as mordants.

The various tints are made by combining different coloured dyes; and it is found in practice that a substance can only be dyed green by a mixture of yellow and blue, chlorophyl, the green of plants, not possessing sufficient affinity for cloth to combine with it. The mixtures requisite to produce the different tints do not belong to chemistry.

Calico printing, as it is called, is the art of dyeing fabrics with *variegated* figures and colours. The expression is not now-a-days correct, for, although cotton goods were at one time subjected only to the process, silk and woollen are now similarly treated. The process, or rather series of processes, by means of which calico printing is effected, are very elaborate and interesting; but an outline of the principle only can be offered here.

2. BLEACHING.

Bleaching consists in decomposing colouring matter. Various processes are followed, all of which depend upon the practical application of one of three principles:—1. Almost all coloured substances become white when they are oxidated; 2. A great many become white when combined with sulphurous acid or sulphuretted hydrogen; and, 3. Nearly every coloured substance is decolorised by chlorine; the chlorine in some cases decomposing the water, and exposing the colour to the liberated oxygen, and in others forming new and colourless compounds. All three modes demand a little amplification.

All colours when exposed to the air have a tendency to fade or become decolorised; and this is owing to their colouring matter combining with the oxygen of the atmosphere. Accordingly, the primitive mode of bleaching was the same as that which is still followed on the small scale, namely, spreading the substances to be bleached upon clean grass and allowing the air to act upon it. It was found that if the goods to be bleached were boiled in alkaline solutions several times, that the process was much expedited. In all probability there is a compound formed between some part of the colouring matter and the alkali, which is more easily oxidated than the original colour; and after the boiling in the solution the material was steeped in sour milk, and any free, caustic alkali neutralised. Even this mode of bleaching required several months. It was discovered by Dr. Horne, about a century ago, that the process might be shortened at least half by immersing the fabric in dilute sulphuric acid. When his plan was followed, the sulphuric acid was probably decomposed and resolved into sulphurous acid and oxygen, each of which possess bleaching properties.

Wool, silk, straw (for bonnets), and feathers, are bleached by the application of sulphurous acid. The articles that are to be decoloured are placed in close rooms in which sulphur is burned. They soon become surrounded by an atmosphere of sulphurous acid, which combines with their colouring matter. The new compound formed is not, however, very stable, and the sulphurous acid gradually escapes from them, or can be made to do so rapidly by the addition of a strong acid.

Is is by means of chlorine, however, that fabrics made of cotton, flax, and hemp, are now bleached, and that in so short a space of time as a few hours. At first pure chlorine was used, but was found injurious to the materials; then chloride of potassium, but the source of the chlorine now always employed is Tennant's bleaching powder, or chloride of lime as it has been called, which contains forty per cent. of chlorine, which is liberated by the addition of an acid.

No. XII.

CULINARY ART.

THERE is no process in domestic economy that cannot be explained, and few, perhaps, that cannot be improved, by chemistry. It may, however, serve our purpose here to notice only, 1. The preservation of articles of food from putrefaction; and, 2. The action of heat upon articles of food, or cookery.

1. THE PRESERVATION OF ARTICLES OF FOOD FROM PUTREFACTION.

The food of man, as we have before seen, consists of matter that has been recently vitalised; that is to say, of the structure of plants and animals that have been generally only for a very short time dead. We have also had occasion to notice that whenever vitality departs from an animal or plant the elements that compose it tend to depart from the rules of life and become subject to those of common inorganic chemistry, or, as it is commonly expressed, putrefy. When they have so putrefied they are no longer nutritious.

Or, to express the same thing in other words, as long as a living structure is alive, the elements that compose it are so arranged as to form starch, sugar, albumen, fat, gluten, and the like, all of which are both palatable and nutritious. If, again, we destroy the life of an animal or plant, as if we produce fatal syncope in the former by bleeding, or a similar state in a potato or wheat plant by removing them from the soil, and thereby cutting off their supplies of nutriment for a little time, the life remains as it were about it, and the elements composing it still retain their nutritious properties and are also sapid to the palate. This, however, is only for a period. Green leaves, as those of spinach, soon cease to be green leaves, and flesh of all kinds soon, under ordinary circumstances, loses all its appearances, and both become a congeries of salts of ammonia, and of sulphuretted and carburetted hydrogen. This is caused by the elements composing them uniting with the elements of air and water. Thus the starch of the potato, which is pleasant to the taste, and which when swallowed supplies carbon for breathing, or is turned into fat, becomes converted (at least in part) into carburetted hydrogen, which is not palatable, and cannot be digested; and the albumen of a piece of beef or pork, which is sapid, and can be converted by the digestive organs into muscle, is by the putrefactive fermentation mainly resolved into ammonia, which is disagreeable to our taste, and in no way nutritious.

The art of man, however, can alter and modify this tendency of dead animal and vegetable structures to run on into putrefaction; and it is not now unusual to eat meat, fruit, even milk, that is some years old, and has perhaps circumnavigated the globe. And it is plain that even landsmen, and that too in countries where there are two harvests in the year, have often very great and indeed indispensable occasion to prevent food, when they have it in abundance, from running into putrefaction, in order that they may have it to eat in times of future scarcity.

In order that the various resolutions into inorganic compounds that we call putrefaction may take place, air and water must be present, so as to afford oxygen, hydrogen, and nitrogen; the combination of which with the elements existing in the organic body constitute the putrefying process. Farther, the changes are very much promoted by the proximity of any substance that can act catalytically, as any substance already putrefying, or, indeed, as any soluble albuminous proximate principle. These facts being borne in mind, there is little difficulty in inferring what are the conditions necessary to preserve articles of food from putrefaction. We may exclude the air, we may take care that no water is present, we may alter the condition of the albuminous principles, or we may combine two of these or all three.

One of the most effectual plans, not indeed of getting entirely rid of the water, but of putting it into such a state that it cannot form chemical combinations, is to freeze it. In the north of Europe this is the common mode of preserving animal food; and in Scotland and other places salmon is thus kept fresh for the London markets. Vegetables may in like manner be so preserved. The length of time that meat, &c., may be kept fresh by freezing is without limit; and in Russia frozen elephants have been picked up that have clearly belonged to a preadamite world, and, encased in ice, have resisted putrefaction during the long roll of almost countless ages.

The water is sometimes driven from any substance that it is desired to preserve from putrefaction by means of drying. Fruits are very commonly prepared in this manner, and we have very familiar instances of this in prunes, raisins, currants, and dried sliced apples and pears. Animal food may also be kept free from putrefaction for a year at least in this manner. The mode of doing it is thus.—The flesh is cut into pieces of a few ounces weight, immersed in boiling water for five minutes as little water as possible being used, and then exposed to a heat of 122° until it has become quite dry. A good deal of the gelatine is dissolved out by the hot water, and this solution of gelatine is evaporated until it is pretty thick, and then heated, and the bits of dried flesh are dipped into it, and the coating of gelatine they get surrounded with allowed to dry; and this dipping is repeated three or four times. In this process, however, besides the drying, the albumen is coagulated, and the access of air prevented by the coating of gelatine.

The Caribbee Indians had a mode of preserving meat by drying; and meat so preserved was called by them *bouchan.* They taught the method to the sea pirates that infested the Spanish main, who extensively used it, and were from that circumstance called buccaneers.

The process of smoking meat, immediately to be noticed, depends partly upon the dissipation of the water; but another cause is still more efficacious.

Alcohol, salt, and sugar possess antiseptic properties, in a very great measure owing to their strong affinity for water, and consequently to their abstracting the water of animal substances that they come into contact with.

It has long been the custom to protect animal and vegetable substances, particularly the latter, from putrefaction, by means of cutting off the supply of air. Storing potatoes in pits is one of the simplest instances of this; and housekeepers have been in the habit of preserving green gooseberries, currants, and even peas, in large bottles, from which the air was carefully excluded. But by far the best method of preserving animal and vegetable matter in this manner from putrefaction is that of M. Appert, and for which he received a reward from the French Government of forty-thousand francs.

This method not only preserves vegetables, but fish, soup, and milk; and articles of food prepared by it will keep for an indefinite period. The process is not difficult, and essentially consists in altogether preventing the access of air. First of all, by boiling or otherwise cooking the viand intended to be preserved, the air is driven from the interior of it (at the same time, too, it must be borne in mind that the albumen is coagulated). After the parboiling, for the process is not carried farther, the substance to be preserved is carefully packed in a tin canister. In the case of meat strong gravy is poured over it, and when vegetables are to be thus preserved some salt and water, the only object in both cases being to fill up the interstices. The canister being *thoroughly* full, a tin cover is soldered on the top, leaving only one little aperture. The canister is then put into boiling water, the heat of which drives off any air that may be amongst the provision, and likewise expands the provisions. When thus hot and expanded, the aperture is soldered up, and the whole allowed to cool.

A very familiar example of preserving articles of food from putrefaction by means of coagulating their albumen is seen in ordinary pickling. Either meat or vegetables preserved in vinegar of ordinary strength, completely resist putrefaction. Creosote is another substance that possesses this power, and it is the main antiseptic agent in smoking meat.

2. COOKERY.

a. Boiling. When a portion of an animal or vegetable structure is boiled, several changes take place. A quantity of salts, and of gelatine or starch, as the case be, or oleaginous matter, are dissolved out along with a portion of the peculiar flavouring principles, and the albumen is coagulated. The water in which the article has been boiled has therefore abstracted a considerable portion of the oleaginous and saccharine principles, and some of the albuminous and flavouring matter. Soup, therefore, is very nutritious, and only differs from flesh or vegetables in containing less albumen. Accordingly, to make it equally nutritious, it is only necessary to add some albuminous proximate principles. The most economical of these perhaps is the gluten of pearl barley, and the solution of flesh and gluten constitutes the very nutritious Scotch broth. Another very common mode of making a perfectly nutritious soup is by adding to the solution of flesh (or stock, as it called in the kitchen) the albuminous principles of carrots and turnips, or making soup *à la Julienne.*

It is quite clear that just as nutritious soup may be made by boiling vegetables as animal structures, if care be taken that the due proportion of albuminous saccharine and oleaginous principles be present. On the other hand, perfect soup may be made from meat alone; for if the meat to be boiled be cut into very small bits, the albumen also is mixed up with the water. This plan is often followed out in kitchens where expense is not regarded.

By far the most economical plan of cooking meat is to boil it and drink the *bouillon* and eat the *bouilli,* as is the universal custom of those who require to live economically in France and Scotland. In England, amongst the same classes, there is a prejudice against the *bouillon,* which is very commonly thrown away. There is a mode of avoiding the waste as little as possible. To understand this, however, it is necessary to consider for a moment what takes place in the boiled flesh (or boiled vegetable).

The great change produced by boiling is the coagulation of the albumen. Albumen by itself coagulates at 140°; but practically it requires a heat of 160°, or otherwise the meat looks raw or red. Another change effected by the application of heat is probably to produce the formation of half-decomposed principles, as kreatine and the like, which are sapid.

Now, if the heat of 160° be suddenly and momentarily applied to a piece of meat, a crust of insoluble albumen is immediately formed upon the outside that effectually prevents the nutritive principles contained in the interior from coming out, while the albumen in the interior is coagulated by conduction. When, then, the *bouillon* is going to be wasted, the plan is to heat the water to 160° or more, before plunging in the article of food intended to be boiled.

b. Roasting. This consists in coagulating the albumen, and producing the half-decomposing sapid principles by means of a current of heated air. The heat is always made sufficiently intense to char the outside. A large quantity of the oleaginous principles melt and trickle out, and a great deal of water is evaporated. In order to prevent excessive evaporation of water, the surface is from time to time coated with fatty matter, or basted. A certain amount of watery evaporation, however, is necessary, in order to produce properly flavoured roasts, and is promoted by exposing the surface to currents of air by means of a spit or jack. A very good illustration of the difference between meat in which the evaporation is allowed, and the same kind of meat in which it is prevented, is to be noticed in a beef-steak cooked in a gridiron and a beef-steak in a pan. Meat baked in an oven does not evaporate sufficiently, and hence is moist or sodden, and it also retains more of the fat.

Broiling is merely rapid roasting.

c. Frying. This consists in exposing articles of food to a much more intense heat than in the previous processes. Oil or fat does not evaporate until heated up to nearly 600°, and frying consists in broiling food in fat having nearly this temperature. The extreme heat probably produces some half-decomposed sapid matter.

No. XIII.

MEDICINE.

The direct and indirect applications of chemistry to medicine are almost innumerable; but most of them are of so technical a nature, that they are not suitable for a work intended for general readers. All that it is proper to attempt here is a rapid sketch of some of the most striking instances of the good effects produced by the science of chemistry upon the preservation of the health and the curing of disease.

There is, for example, the whole subject of the food of man now rendered perfectly intelligible; and yet, until quite lately, the most contradictory, and sometimes the most absurd opinions prevailed amongst the best authorities upon the subject. Cheese, for example, was held by many to be not nutritious; and now we know that it contains so large a quantity of albuminous matter, that it forms one of the best flesh-producers that we know. The cereal grains were held to be less nutritious than butchers' meat; and we now are aware that they contain, in a concentrated form, albuminous, saccharine, and oleaginous principles. Potatoes and tea were long denounced by numerous people; and yet we have now learnt that the former contain a large proportion of saccharine and also some albuminous and oleaginous principles, and that the latter is also probably nutritious. Many well-meaning enthusiasts denounced vinous and alcoholic drinks, and this upon the plea that they contained no *nutriment;* but modern science teaches us that we stand in daily need of an immense quantity of carbon, and that these liquids are one source of this element. Practical experience, indeed, proved that these and many other similar fancies were untrue, and people on the large scale did not give over eating potatoes or drinking tea or wine. But no person could accurately explain the action of the various articles of food and drink. Now, however, we perfectly comprehend it, and we know that the human body consists of about a dozen elementary substances,—that these substances are taken in from without and applied to the blood,—that they cannot be assimilated if taken from the mineral world, but they must have been lately part of the structure of a living being, although slight changes, as those produced by fermentation and cooking, do not destroy their nutritive properties; and, lastly, that all articles of food may be arranged into three classes, the action of members of each of which is now accurately understood,—and the physician is now able, upon well-ascertained principles, to modify the diet so as to suit the necessities of different individuals or of the same individuals when placed in different circumstances.

Then, in various morbid conditions, chemistry can produce great relief by dictating to the physician modifications of the food. There is diabetes for instance, a disorder of the assimilative organs, in which the saccharine proximate principles of food are invariably first converted into sugar, and then excreted, the ultimate consequence being fatal wasting. It is found that by far the most effectual treatment of the disease consists in entirely withholding all saccharine articles of food, and in supplying carbon by means of oleaginous ones. Lastly, indeed, it has been suggested, that the disease so fatal to so many of our fellow-subjects, consumption, is a disease of nutrition, and depends upon an insufficient supply of oleaginous matter; and one of the good effects of cod-liver oil is held by some to depend upon its supplying fat.

We may further remark that, although substances taken from the mineral world cannot afford nutrition, yet that many of them can act chemically upon the fluids of the body and are used as medicines. The natural acid secretion of the stomach is liable to become occasionally in excess and to produce the sensation called heartburn. If an alkali is given the acid is at once neutralised. A modification of the same affection is called water-brash, and in it relief is obtained by combining the acid with a metallic base, and a preparation of bismuth is given. In some instances disease is produced by a deficiency of iron in the blood, probably from the liver excreting an excess of it; and we can easily cure the disease by administering a salt of the protoxide of iron. Curiously enough, salts of the peroxide are not nearly so effectual, and salts of the protoxide always tend to absorb oxygen and become salts of the peroxide. Here, again, chemistry comes in to the aid of the physician, and tells him to add a little sugar to his protoxide, and this prevents any further oxidation. The essential characteristic of gout is perhaps, to morbidly produce lithate of soda. This tendency may be counteracted by means of chemistry; and indeed the good effect of colchicum in this disorder probably depends upon some action of this kind. Various calculi are liable to be gradually deposited from the blood, and their formation in that fluid may likewise be hindered by means of properly applied chemical remedies.

The separation of the active principles of vegetables is one of the additions made by modern chemistry to pharmacology; and it is impossible to over-estimate the value of quinine and morphia. And, lastly, we may notice the antidotes to poisons that chemistry furnishes us. The virulent oxalic acid is rendered innocuous by means of a little lime; acetate of lead is neutralised by Epsom salts; and even the deadly nature of the corrosive sublimate is destroyed by a small quantity of albumen.

* * *

Such, then, is a very imperfect sketch of some of the applications of modern chemistry to the arts. It has no pretensions to give any instructions as to how any particular art should be managed in detail. Such forms no part of the plan of the work, and indeed the writer is perfectly incapable of it; for, with the exception of the kindred arts of agriculture and medicine (*ut alimenta sanis corporibus Agricultura, sic sanitatem ægris Medicina promittit*), he is completely ignorant of all of them. But the object in view has been otherwise, and twofold. First, they have been given as practical illustrations of the great leading idea of this work — the perpetual and continual Phasis of Matter. That which was useless is converted by art into something that ministers to human comfort; but only for a time, for it, too, soon passes away into another and for the time a useless state. And the second object has been to show that, although we have had and may have almost purely empirical arts, yet that still science can modify art, can improve art, can create art, and hence, that she can promote human civilisation, human comfort, and human refinement; and hence, that she can in her own humble way help in preparing man for a state in which the perceptions are more acute, the intellect more clear, and the taste more refined.

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